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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES' EQUIPMENT AND SUPPLIES ASSOCIATION.

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A Welcome Innovation.

For many years the Iron and Steel Institute has been the premier British metallurgical institution with a world-wide reputation. More original discoveries and contributions to ferrous metallurgy have been made public through the Iron and Steel Institute than through any other similar body in the world. The needs of the non-ferrous metallurgists were catered for later by the Institute of Metals, which is now a very lusty organisation. There are some, however, who deplore the division of the field of metallurgy between these two institutions; they regard such a division as wholly artificial, and their view is strengthened by modern research, which is tending to diminish what are regarded as the characteristic differences between ferrous and non-ferrous metals. The similarities in structure and behaviour in certain cases are remarkable, but, however much the division may be deplored on scientific grounds, there is no doubt that it serves an industrial and technical convenience, since the industries are, to a large extent, carried on separately. Obviously the modern co-operative spirit can be served by some measure of mutual approach between these two institutions, and we therefore welcome the news that they are to hold their autumn meetings jointly. They take place in London from September 12-15. The first session will be a joint session, at which Papers having a common interest will be presented. The two later sessions will be carried on independently, but the whole of the remaining functions, the Conversazione at the Science Museum, and visits, including the National Physical Laboratory, the General Electric Company at Wembley, the Mond Nickel Company's Acton Refinery, and finally an all-day excursion to the Dagenham plant of the Ford Motor Company, will be joint affairs.

It is one of the advantages of the Institute of British Foundrymen that it does not suffer from divisions between the ferrous and non-ferrous metals, and we feel sure that those foundrymen and foundry metallurgists who belong to either or both the above institutions will feel special sympathy for the innovation, and will hope that as occasion offers the two bodies will not hesitate to co-operate freely, to the benefit of their members and the industries which they serve.

A Pat on the Back.

It seems but a few weeks ago since we pointed out in this column that for the first time in history a furnace had appeared which challenged the supremacy of the cupola as an economic melting unit for cast iron. Yet it was almost three years ago. The progress recorded since that date of the pulverised-fuel-fired, rotating and rocking furnaces is such that it can definitely be said a new era has been opened up. As far as one can estimate, 17 furnaces are either on order or installed. These have a rated capacity of 112 tons, and are easily capable of making 100,000 tons per annum. An estimate by a sale's engineer of one of the principal companies marketing these furnaces places it as high as 130,000 tons. Geographically, the industrial North has been the principal purchaser, if one can call Yorkshire and Lancashire "North." Capacities range from 3 to a maximum of 15 tons per charge, and the range of materials made includes grey and malleable iron and steel. In addition to the moving furnaces, there are numbers of stationary pulverised-fuel-fired furnaces for melting malleable iron and metal for rolls, for annealing castings and drying cores and moulds. We have no corresponding statistics available for European and American conditions, but we are sure that if we are not already leading the world, we are certainly not lagging behind. Moreover, these developments are contemporaneous with almost unprecedented progress in cupola design and control. We are reasonably satisfied that no country in the world has made greater progress in providing its foundries with high-grade metal for its moulds. There is still a third development—the installation of electric furnaces for the ironfoundries for superheating and refining cupola-melted iron. In the non-ferrous field, it is oil fuel which has captured the imagination of the managers, and here, again, we believe we have registered more progress than any other industrial country. The British foundry industry is setting an example to the whole world in the way it is tackling its melting problems.

XUM

Ganister Costs in Cupola Melting.

By a Metallurgical Correspondent.

The items of cost in cupola-melting practice are often the subject of much discussion. In spite of the enormous accumulated experience of cupola melting which must exist amongst foundrymen, it is often surprising to find gross ignorance displayed on the subject of the prime items of cost in this melting process. This is probably true more of ganister or patching material than of coke costs. There is little published information on this subject, and for this reason the following figures may be of interest. Costs are frequently very intangible things, and there is often a vast difference between actual costs and costs experimentally determined. Experimental determinations are of necessity of short duration, and such things as leakages and losses never attain their true value until the experimental care is relaxed. The following figures are derived from a plant of two cupolas rated at 15 tons per hr. capacity, and refer to the actual costs in that the total invoiced purchases of ganister over the particular period has been taken and compared with the total weight of metal melted over the same period. It is presumed that the stocks at the beginning and end of the period balance, and the periods are sufficiently long to justify this assumption.

Period I.

12 months, commencing from January 1 to December 31.

Total weight of ganister purchased, 284 tons.

Total weight of metal melted, 14,500 tons.

Weight of ganister per ton of metal melted, 0.0195 tons (44 lbs.), approximate.

Period II.

8 months, commencing from January 18 to August 20.

Total weight of ganister purchased, 215 tons.

Total weight of metal melted, 9,650 tons.

Weight of ganister per ton of metal melted, 0.0225 tons (50 lbs.), approximate.

The costs per ton of metal melted, based on several hypothetical rates per ton for ganister, are given below:—

Ganister price per ton.	20s.	25s.	30s.
Ganister cost per ton of metal melted (period I)	4.7d.	5.9d.	7.1d.
Ganister cost per ton of metal melted (period II)	5.3d.	6.7d.	8.1d.

Molybdenum-Tungsten Tool Steels.—The heat-treatment of these steels is the same as is employed for tungsten high-speed steels of the 18-4-1 type, except that lower temperatures are used. Satisfactory hardening is accomplished on small tools at 2,150 deg. Fah. and on larger tools at 2,200 deg. Fah. Tools are preheated at temperatures of 1,450 to 1,550 deg. Fah., and then transferred to the high-heat furnace maintained at the proper temperature, the heating operations being carried out with proper surface protection. High-speed steels should not be held at hardening temperatures too long or excessive grain growth will occur. The resulting coarse structure will cause tools to give inferior results. Molybdenum-tungsten tools are no exception to this rule, and it is essential that holding time at temperature be controlled. Cooling of heated tools is carried out in any quenching oil suitable for high-speed steel. "MoTung" tools are tempered by reheating to 950 to 1,100 deg. Fah., depending on the hardness desired. Maximum secondary hardness is attained at approximately 1,000 deg. Fah., but some forms of tools are tempered beyond this point to obtain greater toughness. Thus, drawing temperatures are definitely lower than those usually employed for tempering tungsten high-speed steels. The tempering operation can be conducted in any convenient manner, such as in an open furnace, properly controlled, or in a suitable bath such as lead, or a satisfactory tempering salt.—"Iron Age."

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

"Implied Warranty and the Sale of Castings."

To the Editor of The Foundry Trade Journal.

Sir,—Your leader in a recent issue of your Journal goes to one of the most important bases of nearly every contract for the sale of goods, and one which, unfortunately, is not always appreciated by the principals to a contract.

If I buy a casting from a firm there is, undoubtedly, an implied warranty under the Sale of Goods Act, whether stated in the contract or not, that it shall be reasonably fit for its known intended purpose, unless the contract contains a clause specifically negating the warranty implied by law.

It is most arguable that the responsibility of the maker of a casting ceases at the supplying of an acknowledged sound casting, assuming that the material of the casting is known to be normal for the purpose, and that the implied warranty that a finished article made from the casting is fit for its intended use as a finished entity devolves on the supplier of the finished article.

I doubt very much if the established custom of the trade which, as you say, is the replacing (only) of defective castings, is of much guidance, as this would not override the implied warranty unless the contract provided for it to do so.

The other interesting point you raise is related to the extent, if any, of consequential damages recoverable following a breach of contract by a founder. Such damages are, under certain circumstances, recoverable, and the founder who does not wish to be subject thereto should make it clear in his conditions of sale. The authority is the case of Robinson *v.* Harman, 1 Ex. 855, in the course of which it was laid down that: "The rule of the Common Law is that, where a party sustains a loss by means of a breach of contract, he is, so far as money can do it, to be placed in the same situation, with respect to damages, as if the contract had been performed." The rule is, however, read as being limited to damages which the parties to a contract might have supposed to be the natural result of a breach of the contract. Special losses are not recoverable unless the contract provides specifically for them in case of a breach.

May I, finally, suggest that the condition of sale which I have marked in ink on the back of the tender form, herewith, of my firm might appeal to other founders. This is not, I am glad to say, the result of previous sad experience, but is to make contractual obligations cease where metallurgical prophesying should cease.—Yours, etc.,

Victor Stobie
(President, Institute of British Foundrymen).

Langholm,
South Drive, Harrogate.
July 30, 1932.

[The printed Conditions of Sale at the back of the tender forms of the Stobie Steel Company, Limited, has the clause cited by Mr. Stobie couched in the following terms: "In lieu of any warranty or other liability implied by law, the liability of the company in respect of any defect or failure in the contract work is intended to and shall be limited to its making any necessary replacements, repairs or restorations to the contract work, and it shall not be liable for any consequential or further damages.

The Skinningrove Steel & Iron Works, Saltburn, will be closed until August 20 to enable the change-over to the electricity "grid" to be carried out.

Random Shots.

It's an unpleasant duty that "Marksman" has to perform this week. It's no less than to take up his pen on behalf of a lady "what's been hard done by" and to inform a certain group of foundrymen attached to a large founding concern in Bottle-by-the-Billboard that they are no gentlemen, even though they do belong to the Ancient Order of Electric Hares and eschew made-up ties. Here are the facts of this deplorable case.

* * *

The Gayway Foundry, at Eastbourne, is at present and unfortunately working at something like a fifth of capacity, and Miss Nellie Snookers, proprietress, has been casting round for some means of increasing her sadly-diminished income. Let "Marksman" hasten to say that, in so doing, her motives have been by no means selfish, but, indeed, patriotic. For the larger her income the larger her contribution to the Government's revenue in the form of income tax. This it was that induced her to take an action of which certain individuals hailing from Bottle-by-the-Billboard have so basely taken an advantage.

* * *

The Gayway Foundry, as you probably know, the most famous "hush-hush" foundry in the world, is a veritable cradle of invention. Miss Snookers presides as a genius over the construction of new types of furnaces, moulding machines, annealing ovens and what you will. The local authorities have every reason to be proud of the Gayway Foundry: they regard it—rightly enough—as one of the sights of Eastbourne, vying in distinction with such attractions as the pier, even the kursaal itself. Well, when Miss Snookers decided to open it to the public this season, the foundry was crowded. It became a fashionable thing to do to join in one of the conducted tours over the Gayway Foundry; and although the price of admission was rather high—but not, let it be said, unduly so—people paid gladly for the privilege of inspecting a works which has added so much to the prestige of the country.

* * *

On the third day after the opening, the second of the day's tours was composed almost entirely of men evidently from the north of England. The commissionaire didn't much like the look of them; they criticised the colour of his uniform. Nor did the girl in the box-office. But they were admitted nevertheless, which goes to show what a fine trusting mind Miss Snookers has, because she herself picked upon emerald-green as the colour of the commissionaire's uniform. And then came the calamity. An attendant, posted on the cupola staging to prevent would-be suicides cremating themselves and ruining the day's melt, saw several members of the party measuring up the sides of a new all-electric annealing oven, inspecting the controls and otherwise trying to discover the hang of the thing. Naturally Miss Snookers confronted these—gentlemen! They admitted quite brazenly their object in coming to the Foundry; it was solely to get full particulars of the oven on behalf of their employees, a rival concern in Bottle-by-the-Billboard. They were evicted instantly through the shute for the old sand, and have not been seen again in the Gayway vicinity.

* * *

"Marksman" has no doubt that his readers, having learned of this outrage, will in future ignore all foundrymen living in Bottle-by-the-Billboard who took part in a mysterious excursion to Eastbourne during the Bank Holiday week. That is the very last they can do. In the meantime "Marksman" has written to the secretary of the Ancient Order of Electric Hares, informing him of the appalling conduct of a number of his members.

Marksman.

Microscopic Tests Acceptation.

MALLEABLE SUB-COMMITTEE'S REPORT CRITICISED.

The presentation of the first Report of the Malleable Sub-Committee of the Institute of British Foundrymen at the Newcastle Conference opened up the topic of the use of the microscope as an acceptance test, around which will centre much controversy for many years to come. Too much importance should not be attached to the first counterblast as every novel suggestion invariably meets with this fate.

Mr. J. W. Gardom, of Dunstable, presented the report, giving a résumé of the main points.

The Chairman (Mr. L. E. Williams, Vice-President) said that the President, Mr. Victor Stobie, had sent a written discussion to the sectional meeting which he had pleasure in presenting.

Hysteresis Losses.

Mr. Stobie wrote that the excellent contribution of the Malleable Iron Sub-Committee was a sign that the Institute of Foundrymen was as intent on leading progress in the founding industry as it was of taking its quota from the industry. The hysteresis loop for malleable iron shown in Fig. 3 was of high interest. It would appear therefrom that the hysteresis losses in malleable iron at an induction of, say, 10 kilolines should be less than those in special high-permeability magnet-steel castings. Was this a correct assumption? If so, it had been a discovery.

The remark that "the maximum permeability is superior to that of the special steel" may possibly lead to a wrong deduction. What ultimately counted in permeability for general electrical purposes was the permeability at magnetisations which would be used in normal circumstances, not at the low value for H at which the malleable iron had its highest permeability. It would, therefore, be of considerable interest to know the magnetisations necessary for inductions, say, 10,000 to 20,000 lines. Additionally, a comparison of hysteresis loops at the above inductions would be most valuable. It was more than probable that eddy-current losses would be lower in malleable iron than in high-permeability steel.

Microstructure as Acceptance Test.

Mr. Tipper wrote that he agreed that specified physical test figures should be raised, and that the size of test-bars should be varied according to the thickness of the casting represented. He thought that it would be possible to specify a desirable type of microstructure, but in the experiments so far conducted there were too many variables satisfactorily to show up the relation between composition, strength and microstructure. He suggested that where physical tests were satisfactory, a microscopical examination would show whether or not the outer skin was liable to fail, due to oxide penetration. This defect was often found in material which was otherwise quite satisfactory. He considered that a careful study of the conditions favourable to rapid oxidation of malleable iron was necessary, such as effect of T.C. Si and Mn to S ratio on the liability to show "peeling" defect.

Mr. L. P. Wilks, of the Fordath Engineering Company, Limited, wrote that the information given in the report should be of great help to malleable iron manufacturers and users, and should give both food for thought. Heat-treatment of malleable castings after welding, brazing, etc., was very important, and up to the present had not received sufficient attention. Many failures had occurred due to brazing or welding of castings, when they had not been subsequently heat-tested. Attention might be drawn to the statement as to the re-solution of graphite. Would re-solution take place in malleable-iron? The paragraph on preparation of test-bars was very interesting, would it not be better to machine test-bars after annealing, particularly when such bars represented automobile and other high-class components with lugs and bosses which were machined all over. Further, it might be better to cast the three sizes of test-bars mentioned—namely, 0.235, 0.564 and 0.977—on a common runner. This would give the advantage that all the bars would contain uniform metal, cast at a similar temperature, and after annealing could represent both large- and small-sized castings, and thin and thick sections of any particular castings. Would Dr. Norbury's graph in Fig. 1 be equally applicable to white-heart and black-heart? Figures for repeated impact and fatigue test would be extremely interesting.

An Acceptance.

Mr. J. V. Murray, who wrote "Yield Point as a Criterion," said that the committee was to be congratulated upon tackling such a problem as test-bars in the malleable industry, where there were so many variables in the production of the work, and it was not to be wondered that many users of malleable had their own specifications. For engineers, the B.E.S.A. specifications Nos. 309 and 310 were suitable, except that no yield point was included. This was a glaring omission and one that should be rectified as soon as possible. A low yield point in white-heart malleable would indicate inferior metal, while a high one in black-heart would also indicate poor material. He did not think that the standard was low. It bore a fair comparison to mild steel, certainly below 20 tons sq. in. was inferior, but the 5 per cent. elongation accompanying the B.S.I. test was more difficult to attain. The German malleable industry had recognised this and had reduced it by nearly 50 per cent. in some cases. The possibility of the inclusion of a repeated impact test, while of great value to the engineering trades, would cause dismay and ultimate collapse to many malleable-iron founders, but the rule-of-thumb method of production was bound to cease and would lead to the scientific control of the many operations involved. There appeared to be no reason why an Izod test should not prevail also. Black-heart malleable should have a hardness test imposed upon it. Should there be a dense picture-frame of pearlite present, this would immediately be discovered by the high Brinell number. The Brinell was superior to the Rockwell in this respect, because of the deeper impenetration, the latter being a surface test.

Melting Methods and Ultimate Value.

In discussing the possibility of having more than one grade of malleable, it should be remembered that the trade had already differentiated these and it was upon the method of melting. Crucible and open-hearth malleable melted were assumed to be of a higher grade and this was confirmed by the selling prices. Cupola-melted metal was considered as inferior. This should not be so. There was very little difference in the mechanical tests. With suitable control, cupola metal could be consistent. Metal giving a tensile strength of 25 to 28 tons sq. in. was being produced regularly. The finest metal in the trade was often spoiled by faulty annealing. Temperature control was vital. There should be no sign of oxygen demarcation lines such as appeared in Figs. 19, 20 and 21. This was a defect and if the article had to be plated afterwards, the deposited metal might peel away along with the oxidised layer, or might cause trouble during polishing and mopping. Even the position of the article in the oven might cause first-class material to become of the inferior type. In one series of experiments conducted on test-bars from the same cast, a loss of from 4 to 6 tons sq. in. in strength occurred. These losses in strength happened when the test-bars were placed in the second row, while the others were in the fourth or just two cans above, the distance being about two feet apart. The average results were 28.7 tons on the fourth can upwards and 23.9 tons on the second can upwards. The proposed after-treatment clause would be of the utmost benefit to the white-heart section of the trade. White-heart malleable might be galvanised, welded, heated-up and brazed without losing its intrinsic properties. There were difficulties in connection with black-heart castings, which might prove their unsuitability for after heat-treatments, but the metallurgist was required for these, as in the case for the next proposed clause, *i.e.*, a microscopical specification and its applications.

Microscopic Tests for Acceptance Condemned.

The adoption of this clause would probably lead to chaos in the malleable industry. The microscopical changes which malleable underwent from the herring-boned white iron to the finished product were more numerous than occurred to any other casting and the changes were heterogeneous. The retention of the bend test would be a better proposition. Bend-test results did give some idea of the microstructure. Even the term ferrite was misleading. In a Paper read at the Birmingham Branch recently it was shown that malleable test-bars could be predominantly ferritic and the angle of bend nil. The gist of the Paper suggested the immediate installation of a metallurgist in every malleable foundry, and this was not what the malleable white-heart ironfounders required. They were assumed to be too expensive. What they desired was one simple test to cover all requirements, and it could not be done. The smashing of a few scrap castings, defective ones at that, was the usual simple procedure that obtained in many white-heart malleable foundries. This should not be so, and it was one reason why the black-heart section had advanced so quickly in the industry at the expense of the white-heart, and it was the bend test-bar which was so spectacular in bending over 90 deg. that was responsible.

He could not agree that no distortion could be detected about ½ in. from the fracture. It could be when the structure was predominantly ferritic, and it was suggested that the best section was about ½ in. from the end of the bar, where there had been no distortion at all. Photomicrograph No. 1 showed such distortion in the shape of lattice lines, and where graphite was present the small nodules caused them to look like matches. Where the structure was pearlite in its varying forms these "matches" could not be seen. Obviously there was very little distortion in a structure that could not be deformed in a cold state. Should a microscopical examination be decided upon, the two first conditions must be: (1) Absence of primary graphite and (2) absence of free cementite. Upon these two depended everything that mattered in malleable. In conclusion, it might be mentioned that a mixture of a 2 per cent. alcoholic solution of picric acid and a 2 per cent. nitric acid in alcohol gave the best results in etching malleable. As a medium for examination of failures, the microscope was invaluable, but its introduction into test-bar specifications was impossible to the industry as a whole if the industry was to be kept on as it was at present.

Simplification of Acceptance Tests.

Mr. J. G. Pearce, director, British Cast Iron Research Association, wrote that both the Paper and the work of the Committee were very valu-

XUM

able, particularly the work on the unmachined test-bar. He did not think that the existing B.S.I. malleable specifications should be blamed on the ground that they were too low. After all, until 1927 there were no specifications at all, and it was the policy of the B.S.I. to put out specifications which in the first place represented a minimum that the trade as a whole could reach. Higher specifications for special materials and special classes of work usually followed. It would be noted that, although the Report suggests that the specification is too low, none of the white-heart materials tested shows elongation figures consistently higher than the specified 5 per cent. The suggestion that variable figures might be specified for one standard test-bar (instead of adopting varying diameters of test-bar) was undoubtedly a convenience to the manufacturer, but in practice led to difficulties. The principle had been adopted in the United States for grey iron to meet the necessity for varying the sizes of test-bar to suit the size of casting and metallurgical opinion in that country was rapidly coming to the view that the British scheme of a series of test-bars was more satisfactory.

Microscopic Tests Unsuited for Acceptance Purposes.

With reference to microstructure as an acceptance test, Mr. Pearce insisted that nobody could have a greater belief than himself in microexamination as a source of information about ferrous materials, particularly defective materials. For research and investigation it was essential.

This, however, was very different from using it as an acceptance test, which would be very dangerous. Ever since specifications for ferrous metals had been used in this country it has been a fixed principle that the requirements of users could be expressed in terms of definite and simple mechanical tests. The user or designer usually wanted this information, and he did not require anything further. Micro-examination could not take the place of mechanical tests so that it would be supplementary to them and would therefore put an additional burden on the manufacturer. It would open the door to endless amount of argument and difficulty, whereas mechanical tests were easily interpreted and created little trouble, even with the least well-informed inspector. He did not agree that the technique of micro-examination was simple and widespread. His experience was that the number of foundries using micro-examination in daily production was very small and that the technique was comparatively little developed. The Paper illustrated this, while photographs 15 to 18 inclusive were admirable. Figs. 19 to 24 were less satisfactory.

There was no doubt whatever that the adoption of this for malleable iron would soon spread to grey iron and that the manufacturer would be compelled to make to a structure as well as to mechanical tests. He took the view that the method of production, composition and microstructure were no concern whatever of the user as long as the specified mechanical tests were met. On any other basis the work of the founder would be virtually impossible.

With reference to the B.C.I.R.A. standard magnifications cited in the Report, these cover the whole range of grey and malleable iron, and for malleable it was usual to work on the basis of a magnification of 25 on an etched structure. The picric-acid etch was used as most suitable for general work, but actually for ferritic irons of the black-heart type illustrated in Figs. 15 and 16 alcoholic nitric acid was preferable. When pearlite was present, picric acid was better, as is illustrated by Fig. 18, which is distinctly better than Fig. 17. The magnification of 250 had recently been replaced by 200.

The Chilean Government is reported to have authorised the construction of a pipe-line from Bolivia to the Chilean coast.

The Aachen Foundry Institute.

By J. G. Pearce, M.Sc.

In the issue of the Foundry Trade Journal of June 2, 1932, the writer described the opening ceremony of the Foundry Technical High School's new melting shop and experimental foundry at Aachen. The following gives a few details of this new department and will convey some idea of the resources now available at the School. The opening ceremony was performed in the presence of representatives of the German associations of ironfounding

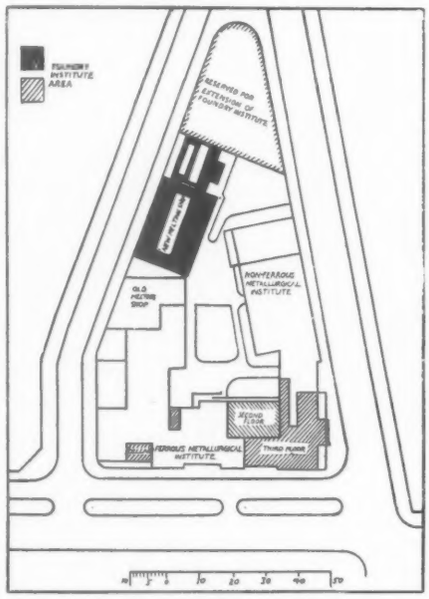


Fig. 1.

employers, grey-iron founders, steel and non-ferrous metal founders.

That part of the metallurgical school at Aachen devoted to foundry education is housed in the second and third floors (shaded in Fig. 1) of the Neumann Institute, which itself covers the metallurgical work of the school as a whole. This space covers an area of 33,000 square feet and provides laboratories equipped for dealing with microscopic examination, physical measurements, X-ray examination, furnace room, chemical and corrosion laboratories and laboratories for the determination of oxygen and other gases in ferrous metals. The new melting shop is shown in black in Fig. 1, and near it is the

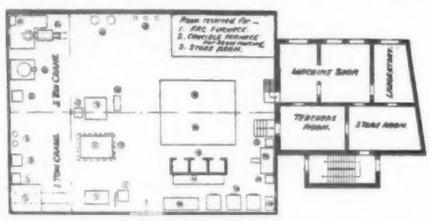


Fig. 2.

Fig. 2 shows the plan of the shop, the equipment of which includes:—

Weigh scales, core bench, drying oven, core oven, gas-fired annealing oven, gas-fired muffle furnace, moulding pit, moulding bench, oil-fired ellipsoid furnace, blower, electrical annealing furnace, oil-fired cupola, blower, cupola with receiver, pig moulds, oil-fired muffle furnace, ladle heaters, refractory bunkers, moulding machines, sand thrower and tumbling barrel, stores, compressor, sand bunkers, sand preparation, smith's hammer.

old melting shop. Another building is devoted to the technology of foundry work. On the ground floor of this is a machine shop, on the first floor a collection of castings, both good and bad, and on the second floor a valuable collection of patterns which passed to the Aachen Foundry Institute after the Düsseldorf Foundry Exhibition in 1929. The corner area shown in Fig. 1 is reserved for further extensions. The ultimate object in view is to remove to this site the laboratories mentioned above for foundry work now occupying the second and third floors of the main metallurgical building and thereby allow for extension of the latter in its own building. This will make the Foundry Institute entirely self-contained.

The new melting shop is 80 feet long and 60 feet wide, arranged in two bays each served by cranes, a one-ton and a three-ton respectively. Fig. 2 shows a plan of the shop. The bay served by the larger crane contains the melting plant and the other the sand-preparation plant, the hand and machine moulds and the drying ovens. Fig. 3 shows an interior view and some of the melting equipment. It shows to the extreme right the cupola and staging, with receiver; to the left an ellipsoid melting furnace

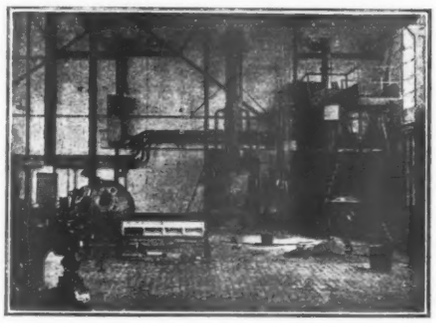


Fig. 3.

and in the middle a new type of oil-fired cupola. In this furnace the metal is apparently charged on to a coke bed and melted. It then falls into a kind of receiver heated by several burners, fed with heavy oil and air which has passed through a preheater warmed by the waste gases passing up the stack.

Catalogue Received.

Silica Firebricks.—Messrs. John G. Stein & Company, Limited, Bonnybridge, Scotland, have sent us an advance copy of their new catalogue covering their wide range of refractories. Those of us who have tried to design structures will readily admit that we found the catalogue issued by a prominent firm of steel manufacturers most useful in depicting just what sections were commercially available. The catalogue under review will be equally sought after, because it shows in a very complete manner just what has been standardised and what is available for furnace construction. The compilers have been very generous in including a vast amount of technical data not too easy to find elsewhere. It is printed in imitation art paper and very profusely illustrated. We were specially attracted to the examples of furnaces used in industry. The highest compliment we can pay this excellently-presented brochure is that if we were designing a furnace it would constantly be at our elbow. Readers receiving a copy of this catalogue can indeed count themselves fortunate.

Coreless Induction Furnace.—The largest furnace equipment so far installed, is said to be in service in an American steel plant. The equipment consists of a 4-ton furnace energised by a 1,250-k.v.a. motor-generator set. The usual charge to this furnace is about 8,000 lbs., and requires from 2 to 2½ hrs. to melt. This equipment, when operating 24 hrs. per day, will produce about 40 tons of steel. Charges of 100 per cent. stainless-steel scrap are being converted successfully into good ingots. Loss of alloys in remelting this light scrap is practically negligible.

Inclusions—Their Effect, Solubility and Control in Cast Steel.*

By C. E. Sims and G. A. Lillieqvist.†

The following presentation is more a summation of observations made and conclusions drawn over a period of three to four years than a report of experiments made with a definite objective. Tests were made, of course, to verify hypotheses, but the large mass of data was collected incidental to other work. Lack of space forbids the presentation of more than a few of those data. On the other hand, it is unfortunate that some of the most illustrative examples are not available. The work is admittedly incomplete, but is presented in the hope that it will stimulate further work along a similar line. The answers to many of the questions left unanswered by this Paper will be found only after long and painstaking study, such as is scarcely possible in a commercial laboratory where problems of immediate importance consume most of the time. It is also hoped that this study will in some measure throw light on some of the dark spots of steelmaking, and help to clarify some of the annoyingly vague references to "good practice."

Only cast steel was studied and the conclusions apply to cast steel, but it is the author's opinion that the quality of rolled or forged steel is largely dependent on the quality of the ingot, which is a casting. Although this discussion deals almost entirely with inclusions, it is important that the reader understand that only those natural inclusions which owe their origin to the solubility of certain materials in steel and to the chemical reactions of steelmaking are considered. Accidental inclusions, such as entrapped particles of slag, nozzle, runner, or mould are outside its province, and are not considered. Such accidental inclusions are always dangerous and should be carefully avoided.

Relation between Ductility and Non-metallic Inclusions.

In September, 1928, an acid electric furnace was put into operation at the Indiana Harbour plant of the American Steel Foundries. Following the usual practice, aluminium additions were made in order to obtain sound castings. Immediately the problem of low ductility arose. Previous to that time, only open-hearth steel was produced, and, aluminium being used rarely in that steel, there had been practically no trouble with low ductility in the lower carbon range.

A study of the problem was undertaken at the research laboratory, and soon it was observed that there was a characteristic and consistent relation between the ductility and the type of inclusions present. It was noticed, for instance, that when aluminium was added to a deoxidised steel, not only were fine dustlike groups of alumina produced, but a profound change usually took place in most of the other non-metallic inclusions. Accompanying this change in the inclusions is a decrease in ductility, principally in the reduction of area, although the elongation is also affected. Occasionally the addition of aluminium does not produce this characteristic change in the inclusions, and, when it does not, the ductility is likewise unaffected. Sometimes low ductility is found in steels that have not been treated with aluminium, but in these steels is found a type of inclusion similar to those produced by the addition of aluminium.

In Figs. 1 to 3 are shown the unetched micrographs of three typical heats from a 3-ton acid electric-arc furnace. The compositions and physical properties of these steels are given in Table I. Although the compositions are similar, there is a marked difference in the ductility. Figs. 1 and 2 have the type of inclusion characteristic of non-ductile steel. Fig. 2 is somewhat more pronounced than Fig. 1 and also has lower ductility. Fig. 3 is equally characteristic of a ductile steel. Aluminium to the amount of about 12 oz. per ton was added in the ladle to all three of these heats. While the aluminium addition produced its usual effect on the inclusions and ductility of Figs. 1 and 2, it did not have a similar effect on Fig. 3. This last example illustrates the statement made above that the addition of aluminium to steel does not affect the ductility unless it also changes the nature of the inclusions. The inclusions in Fig. 3 are the kind that would ordinarily be expected were no aluminium added.

There are shown in Figs. 4 and 5 two steels of similar composition but of higher carbon and manganese than those of Figs. 1 to 3. The latter steels were made in a high-frequency induction furnace under similar conditions and were given the same heat-treatment. The analysis and physical properties are given in Table I. No aluminium was added to either steel; yet it is readily seen that No. 30 has the type of inclusions that unmistakably marks it for a steel of low ductility, while No. 32 is just as plainly stamped for high ductility. Table I proves No. 32 to be superior in strength as well as in ductility. The higher manganese content probably accounts in part for the higher strength of No. 32.

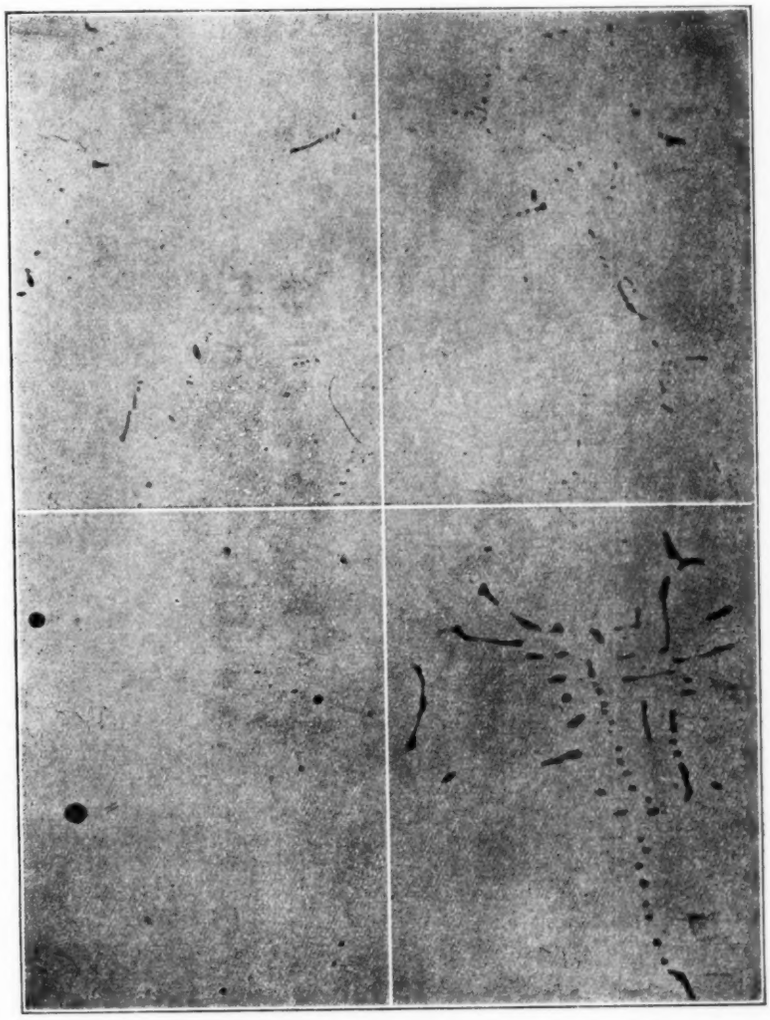


Fig. 1. Fig. 2.

Fig. 3. Fig. 4.

Fig. 1.—Acid Arc-Furnace Heat 255 × 250. Example of Steel with Low Ductility due to Al Additions.

Fig. 2.—Acid Arc-Furnace Heat 256 × 250. Examples of Steel with Low Ductility due to Al Additions.

Fig. 3.—Acid Arc-Furnace Heat 257 × 250. Examples of Steel with High Ductility in spite of Al Additions.

Fig. 4.—Induction-Furnace Heat 30 × 500. Eutectic Type of Inclusions in Steel not treated with Al.

Although the examples just referred to are considered typical rather than extreme, many intermediate structures are found which have intermediate ductilities corresponding to the inclusions. Photomicrographs of two such steels are shown in Figs. 6 and 7. These steels have both the globular inclusions of ductile steel and the elongated chain type of low-ductility steel. Of these steels, one (No. 199) had no special

* Technical Publication No. 453 of the American Institute of Mining and Metallurgical Engineers.

† Research Metallurgists, American Steel Foundries.

deoxidiser added, while the other (No. 208) was treated with calcium silicide. Another type of inclusion which confers intermediate ductility is shown in No. 207, Fig. 8. This is referred to as the angular or free-formed crystalline type of inclusion. It seems to occur most frequently in steels containing over 1 per cent. of manganese. Calcium silicide was used in deoxidising this steel.

But for lack of space, numerous other examples could be cited. Hundreds of specimens of steel have been examined microscopically, and a most remarkable consistency has been found between the ductility and the nature of the inclusions. Due allowance must be made, of course, for the composition of the steel. This relation has been found so consistent, in fact, that the ductility of a cast steel can be predicted after a microscopic examination. In test cases, steels have been placed in the order of their ductilities before the physical tests were made, and in no case has there been an error made except where the difference in ductility has been so slight as to be negligible.

The factor on which it is desired to place greatest emphasis is that it is not the amount of inclusions that directly affects the ductility, but rather the arrangement of the inclusions that are there. The reason for the strong emphasis on this point is that this rather obvious conclusion has been reached so seldom and by so few observers. A notable exception is G. F. Comstock,[1] who has charged aluminium additions with causing the sulphides to be arranged in streaks in a sort of fragmentary network, and this network of sulphides in turn with being largely responsible for the low ductility.

References too numerous to mention can be found in the literature, attributing the low ductility of aluminium-treated steel to a few inclusions of alumina. These alumina inclusions usually occur in such small and widely scattered groups as shown in Fig. 9. Ordinarily they are so scarce that they will not show in a photomicrograph unless they are intentionally included. No logical explanation has ever been advanced, to the writers' knowledge, as to why these relatively few groups of alumina should have any more effect on ductility than the inclusions found in steel not treated with aluminium. They occur in most steels to which aluminius has been added, but the authors believe that they have an insignificant influence on ductility. It has already been shown (Fig. 4 and Table I) that low ductilities are possible in the absence of alumina when the inclusions are of a certain type.

On the other hand, a steel may hold considerable alumina and still have good ductility; for instance, heat 564, Fig. 9, shows a steel that contains scattered groups of alumina inclusions (Composition: C, 0.266; Si, 0.41; Mn, 0.68; S, 0.031; P, 0.014 per cent.), and yet has the following properties in the normalised state:

Ultimate strength, tons per sq. in. ..	34.2
Yield point, tons per sq. in.	21.2
Elongation in 2 in., per cent. ..	32.5
Reduction of area, per cent.	56.0
Izod impact, ft.-lb.	39.0

In spite of the presence of alumina, the other inclusions are globular and random in their arrangement, which accounts for the high ductility. Such a steel is not apt to occur in usual steelmaking practice, and this one was produced especially to test this point. The procedure was first to deoxidise an induction-furnace heat in the usual manner with ferro-manganese and ferro-silicon. Then, an amount of aluminium wire equivalent to 2.2 lbs. per ton of steel was added and allowed to diffuse. This unusually large quantity of aluminium accounts for the large groups of alumina inclusions. Third, a quantity of iron ore was added, and after a short time allowed for reaction, the heat was poured into a standard 60-lb. test block.

Unfortunately, no steels have yet been produced free from non-metallic inclusions, and therefore no data on the physical properties of such hypothetical steels are available. However, the quantity alone of inclusions in the range of amounts ordinarily found in cast steels does not seem to have any marked effect on the strength, ductility and impact values of the steel; and considerable doubt is felt as to whether any considerable improvement would be found in the properties of so-called "clean" steels. It is certain, on the other hand, that a steel can be "dirty" and still have excellent physical properties providing the inclusions are of the right type. A good example of this is the steel of heat 534, the photomicrograph of which is shown in Fig. 10. This is regarded as a rather dirty steel; yet in the normalised condition it had the following properties:

Tensile strength, tons per sq. in. ..	52.7
Yield point, tons per sq. in.	38.4
Elongation in 2 in., per cent. ..	28.0
Reduction of area, per cent.	60.8
Izod impact, ft.-lb.	60.0

There being so few reliable data concerning the effect of inclusions on the endurance value of steel, this phase of the physical properties is omitted from the discussion.

Reasons for Difference in Ductility

A close study of the photomicrographs in Figs. 1 to 5 clearly reveals the reason for the variation in ductility with different types of inclusions. Those accompanying high ductility as represented by Fig. 3 (No. 257) and Fig. 5 (No. 32) have the following essential characteristics. They vary greatly in size, but are practically all globular in shape and are distinctly random in their arrangement and distribution. There are usually three kinds: the dark coloured silicates, the light grey sulphides, and those containing substantial portions of both sulphide and silicate. Probably all have some of both sulphide and silicate, as they are practically miscible in the liquid state.[2] But the really important point is that they are true inclusions occurring mostly within the crystals of steel and leaving the latter in a continuous coherent phase. Thus there is the very minimum of interference with the plastic distortion of the steel.

Fig. 5.

Fig. 6.

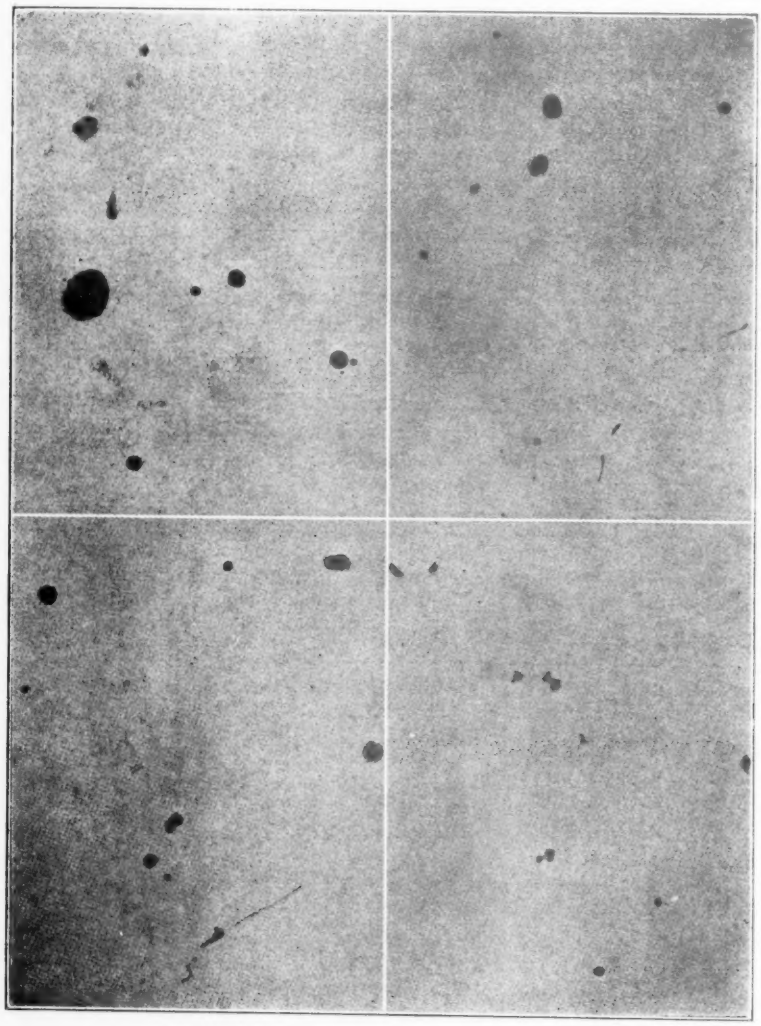


Fig. 7.

Fig. 8.

Fig. 5.—Induction-Furnace Heat 25 × 500. High Ductility.

Fig. 6.—Induction-Furnace Heat 199 × 250. Intermediate Ductility.

Fig. 7.—Induction-Furnace Heat 208 × 250. Treated with Calcium Silicide. Intermediate Ductility.

Fig. 8.—Induction-Furnace Heat 207 × 250. Treated with Calcium Silicide, Angular Inclusions. Intermediate Ductility.

1 G. F. Comstock: "Aluminium and Titanium as Deoxidisers." *Iron Age* (December 4, 1924), 1477.

2 Levy: Iron and Steel Inst., *Carnegie Schol. Mem.* (1911), 3, 260.

When there is low ductility, as represented by Figs. 1 and 2 (Nos. 255 and 256) and Fig. 4 (No. 30) the inclusions have an utterly different character. When this type is the result of aluminium additions, small scattered groups of dustlike particles of alumina are present, but these are usually so scattered and few as to be rather inconspicuous. The other inclusions occur as elongated club-shaped particles or chains of round, evenly sized and spaced dots. It is probable that those appearing round are really elongated inclusions shown in cross-section. They are confined exclusively to the grain boundaries of the primary crystals or dendritic fillings, and have all the earmarks of being a part of a eutectic that was the last mother liquor to solidify. More evidence that they are in fact a part of a eutectic formation will be given later. Occurring as they do, they form a continuous network or envelope about all the primary crystals of steel. Thus they constitute the continuous or external phase, with the steel crystals forming the discontinuous or internal phase. Or to be more exact, since a phase must be homogeneous, this eutectic is a matrix in which the crystals of steel are embedded. These primary crystals or dendrites must not be confused with the grains or crystals as seen under the microscope after the steel has cooled down to room temperature and is in the alpha state. This eutectic appears to be brittle, and when plastic deformation occurs, it cracks before the metal within has much chance to flow. This results in an amorphous, woody type of fracture and consequent low ductility. While there often appears to be a lower total quantity of inclusions in aluminium-treated steel, they are strategically arranged to work the greatest harm to the ductility.

Table I.—*Typical Heats from 3-ton Acid Electric-arc Furnace.*

Heat No.	C	Mn	Si	P	S	Y.P. Tons per sq. in.	M.S. Tons per sq. in.	E. per cent in 2 in.	R.A. Per cent.
255*	0.23	0.69	0.40	0.021	0.042	18.8	32.9	21.5	27.2
256*	0.24	0.70	0.54	0.020	0.044	22.3	35.9	19.0	22.3
257*	0.23	0.63	0.41	0.021	0.040	19.1	31.9	30.0	53.3
30	0.469	1.21	0.69	0.022	0.045	31.0	51.4	18.0	28.0
32	0.468	1.31	0.75	0.021	0.040	32.4	54.7	21.0	44.0

* Treated with aluminium in ladle at furnace spout.

Evidence of Solubility of Inclusions.

The foregoing argument is obviously based on the premise of the solubility of inclusions in liquid steel. This premise is strongly supported by the evidence accumulated during the present investigation. The possibility of the solubility of inclusions in liquid steel has been discussed from time to time, but has not been accepted generally by metallurgists. Ziegler[3] suggested the solubility of inclusions in gamma iron as well as in liquid steel. Probably the most comprehensive discussion of this subject is by Wohrman,[4] who points out that although the solubility of iron oxide and iron sulphide in liquid iron has been proved, the solubility of the mixed sulphides and silicates has been neither proved nor disproved. He does give evidence that strongly indicates that a considerable number of these inclusions are actually dissolved in liquid iron.

Observations made almost daily during the three years during which the present data were collected have led inevitably to the conclusion that the common inclusions of steel, with the probable exception of alumina, are to a large degree soluble in the molten steel. They form as inclusions during the cooling and solidification of the steel.

One of the earliest and most persistent phenomenon observed was the fact that small castings invariably contained small inclusions, while large castings just as surely carried proportionately large inclusions. This was extremely puzzling until explained by the hypothesis of solubility. An interesting example of this occurred during some tests at one of the plants. These tests were run on a basic open-hearth furnace and were for the purpose of trying out some recently advanced theories. Certain samples were taken which, when examined under the microscope, showed no inclusions at all. Had clean steel really been produced? The samples were sent to the research laboratory for checking, and when higher magnification was used the steel was found to contain quantities of very small inclusions which had been almost indiscernable at the lower magnification. It turned out that the samples had been cast as small pieces in chill moulds, which accounted for the small size of the inclusions. Steel cast against a chill always has very small inclusions close to the chill, and they increase in size with distance from the chill.

There is no change in either the size or quantity of inclusions with time of holding in the liquid state, providing other things are equal. Probably everyone who has contemplated the problem of elimination of inclusions has conceived the idea of holding the steel in the liquid state for a sufficient time to allow the inclusions to rise to the surface and enter the slag. This method has been tried by nearly everyone who has had the opportunity, including the authors, and with universally disappointing results. The method will not work, and it must be because the inclusion-forming material is not in a condition to rise. Calculations[5] have been made as to the rate at which inclusions of various sizes would rise, and some of the larger ones are given rates of several feet per minute. Proof that undissolved foreign material actually does rise rapidly in steel is given by the fact that accidental inclusions of sand, bottom material, etc., are so rarely seen in steel.

In order to obtain experimental evidence on the foregoing observations, the following experiment was made. The experiment was repeated for purpose of checking, but the results were in such close agreement that results of only one experiment are reported. A heat (composition: C, 0.266; Si, 0.36; Mn, 0.77; S, 0.041; P, 0.29 per cent.) was made in an acid open-hearth furnace, using standard practice. A bifurcated spout was used in tapping, and 6 tons was run into a small ladle, while the other 20 tons was run into a larger ladle. To the small ladle was added 6 lbs. of aluminium, or 1 lb. to each ton of steel. It was tapped at 3.05 p.m. Twenty minutes later, between 3.25 and 3.31, a series of test blocks was cast from the small ladle. In this series, there were blocks of ¼-in., 1-in., 3-in., 6-in., 9-in., 12-in., and 15-in., section, all gated at the bottom and cast in dry sand. At 3.27, or 22 min. after tapping, a 9-in. block was cast from the large ladle, and then from 3.48 to 3.52, or 45 min. after tapping, a series like the above, running from ¼ to 15 in. was cast. Risers as large as the blocks themselves were used on all these castings, to ensure solidity and to allow entrapped dirt, etc., to float out of the portion to be used.

Specimens for micro-examination were cut from the centre of each of these sections. Photomicrographs of the specimens were taken from the blocks cast from the large ladle. No aluminium was used in these, and it was noted how uniformly rounded all the inclusions are. The particular spot selected for each picture was chosen because it had the largest inclusions to be found in that specimen. While there is a great variety of sizes of inclusions in each section, it was readily seen that there was a consistent increase in the average and maximum size of the inclusions with increase in the section of the casting; in other words, the average size of the inclusion in a given heat of steel is dependent on the rate of solidification. This signifies, in turn, that the inclusions are formed during solidification and therefore do not exist as such prior to it.

Although this steel was held in the ladle for 45 min., there was no dearth of inclusions. Like-

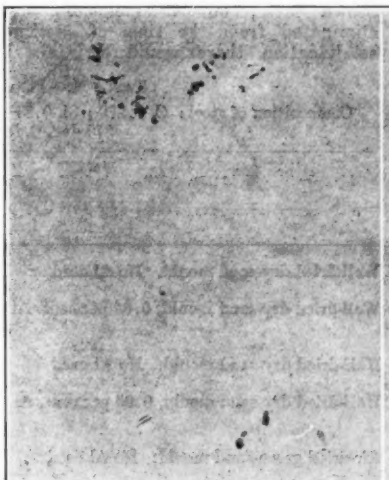


Fig. 9.

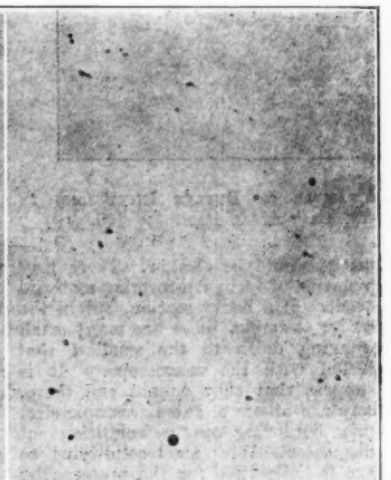


Fig. 10.

Fig. 9.—Induction-Furnace Heat 564 × 200. Alumina or Aluminium Silicate Inclusions at Top of Cut.

Fig. 10.—Induction-Furnace Heat 534 × 100. Example of "Dirty" Steel with High Ductility.

[3] M. Ziegler: "Sur le Crystallisation du Fer Alpha." *Rev. de Met.* (1911) 655 *et seq.*

[4] C. R. Wohrman: "Inclusions in Iron." Amer. Soc. Steel Treat. (1928), 14, 542-548.

[5] U.S. Bur. Mines *Rept. of Investigations*, 3081 (1931).

wise, in the two 9-in. sections, one of which was cast 22 min. after the tap and the other 23 min. later, there is no noticeable difference in either the size or quantity of inclusions. Holding time is apparently without influence on the quantity of non-metallics held, which, of course, is quite in line with the theory of solubility.

An integration of the inclusions by the inclusion-count method will show an apparently greater amount of non-metallics in the large sections, like the 12-in. or 15-in. sections, than can be seen in the small sections, such as the ¼-in. or 1-in. sections. All sections having been poured consecutively from the same ladle of steel, it is obviously impossible to have an actual difference in non-metallic content. Indeed, if there could be a difference, it would seem, on the basis of current beliefs, that the sections with the

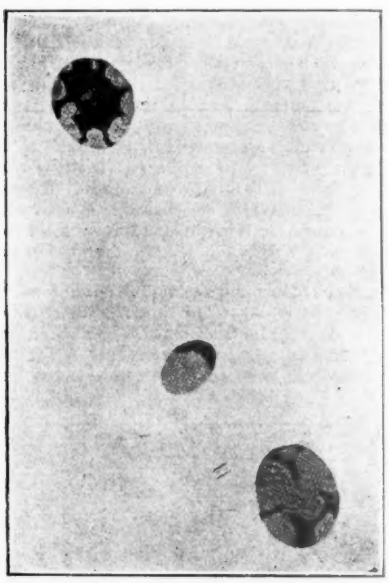


Fig. 11.—Example of Duplex Inclusions in 24-in. Cast-Steel Ram. × 400.

larger inclusions would be cleaner. There may be some segregation of inclusion-forming material toward the centre of a heavy section, but in the ¼-in. section, for example, there are many small inclusions ranging down to the smallest that can be detected with the microscope. It is logical to suppose that they do not end there, and that there are others of submicroscopic size, perhaps some bordering on a condition of molecular dispersion. With steel solidifying so quickly, there is little time for the preferential precipitation of the non-metallics in solution or for the agglomeration of the inclusions after their formation.

In all sections there is a wide range of sizes in the inclusions, even the ¼-in. section having a few fair-sized ones. This seems to indicate that the solubility of the non-metallics is limited and varies with the temperature. As the steel cools toward the freezing point, a few inclusions are formed first. Then as the temperature drops and the solubility further decreases, the non-metallics are preferentially precipitated on those already formed, although new ones are forming constantly. At about the freezing point, when the solubility changes rapidly, there is a more sudden precipitation of very small inclusions. The statement that high temperature increases the solubility for non-metallics has been verified by numerous observations. Very hot heats are "dirty." Heat 534, shown in Fig. 10, was hotter than the average heat.

Although in this discussion numerous references are made to the amount of non-metallics present as inclusions, let it be understood that no actual quantitative determinations were made. Unfortunately, there was no opportunity for work on this subject. Opinions given are based on a careful scanning of a polished section under the microscope in comparison with other steels. This is roughly equivalent to an inclusion count and, although one might easily be mistaken in estimating two steels very similar, any large difference would be readily detected. Allowance is always made for the size of the section as cast. No large differences have been found in the quantity of inclusions in steels made by ordinary processes. One of the outstanding observations has been that in steels of not too great a difference in composition, whether made in the open-hearth furnace, arc electric furnace, or high-frequency induction furnace, with day-to-day variations in practice, year in and year out, there are but slight variations in the quantity of inclusions. Heat 534, Fig. 10, has been mentioned as an unusually dirty steel, but from the examinations made it would take careful comparison to establish that it was any worse than the 1-in. section cast. There are factors that operate to vary the character and quantity of inclusions, the most important being composition and tempertaure. These will be discussed later. A high sulphur content is certain to be accompanied by a high inclusion content.

Is not this regularity of inclusion content a further evidence of solubility, and does it not attest that the inclusions are present to the saturation point? Any amount over the saturation point seems to be quickly eliminated from the bath. Of course, it can be argued that the iron oxide present in the steel before deoxidation controls the quantity of inclusions formed, and that iron oxide having a limited solubility, the inclusions must also be limited. This is undoubtedly true to a great extent, as will be shown later, but if inclusions were being eliminated from the time of deoxidation to solidification there would certainly be larger variations than have been found. Furthermore, there is great uniformity and consistency in the inclusions throughout all the steel of a given heat, provided the cooling conditions are similar. A certain degree of concentration of inclusions is known to exist where the zone of columnar dendrites ends in an ingot, and also in the risers or sink heads of castings and around shrinkage cavities; and, of course, the inclusions are larger in the centre of a heavy section than near the surface.

In the series cast from aluminium-treated steel there was a similar effect due to size of section up to 6 in.; above 6 in., there was little change. The same characteristics are found in both sections, the only difference being that everything is on a larger scale in the 9-in. section. With the exception of the clusters of alumina (or aluminium silicate), the inclusions are confined to the dendritic fillings. In the larger section, the rate of cooling was slower and the primary crystals larger. This caused a greater concentration of the inclusions into broader and coarser bands than in the smaller section, but they have not varied in the least from the habits of a eutectic; in fact, the larger section shows the eutectic formation to greater advantage. Even the aluminium silicate particles are larger and are in bigger clusters in the large section, which seems to indicate at least slight solubility for them.

As has been mentioned earlier, when aluminium is added to steel already deoxidised with manganese and silicon, a profound change usually takes place in the character of the inclusions to the detriment of the ductility. This change takes place with great rapidity, as will be shown by the results of the following experiments. Two standard test-bar moulds made of dry sand, thoroughly dried and still warm from the drying oven, were placed side by side. These were poured consecutively from the same ladle of plain carbon steel, with the difference that in the second a piece of ⅛-in. aluminium wire was fed into the stream of metal as it entered the downgate. This was repeated with two dry sand moulds which were only partly dried, two green-sand moulds which were skin dried by being allowed to stand open for about two hours, and two green-sand moulds that were moistened on the surface with a fine spray of water just before they were closed.

The test-bars were normalised by heating to 870 deg. for 2 hrs. and cooling in air. The physical results are given in Table II. Attention is called to the striking similarity in the properties of all the bars poured without addition of aluminium and to the uniformity with which the aluminium affected the properties of the others. The aluminium had the effect of increasing the yield point and decreasing the ductility and impact resistance. This is cited because it has been claimed[6] that aluminium affects steel chiefly when alumina is formed by oxidation of the aluminium by migrant gases in the mould. These migrant gases are supposed to occur only in improperly prepared moulds. This experiment shows, however, that the condition of the mould has little to do with the effect of aluminium on the ductility of the steel.

The character of the inclusions in the various types of mould was very similar, and the interrelation of ductility and type of inclusion was clearly established. In this case, both the inclusions and the ductility are not affected as much as in heats 255 and 256 of Figs. 1 and 2. The time interval between the addition of the

Table II.—*Results on Test-Bars with and without Aluminium.*

Composition of steel: C, 0.278; Si, 0.37; Mn, 0.79; S, 0.035; and P, 0.030 per cent. Heat-treatment: 870 deg. C. for 2 hrs. Cooled in still air.

	Yield point, lb. per sq. in.	Ultimate strength, lb. per sq. in.	Elongation, per cent in 2 in.	Reduction of area per cent.	Average Izod impact, ft.-lb.
Well-dried dry-sand mould. No Al used ..	47,300	78,900	31.5	54.4	37.0
	47,800	79,100	31.0	54.9	
Well-dried dry-sand mould, 0.05 per cent. Al added	50,600	79,550	26.5	38.2	31.0
	47,900	79,200	27.0	42.0	
Half-dried dry-sand mould. No Al used ..	46,200	79,500	31.5	57.0	37.0
	47,200	79,500	30.5	54.4	
Half-dried dry-sand mould, 0.05 per cent. Al added	51,000	80,150	26.5	37.6	29.0
	51,250	79,600	26.5	38.9	
Air-dried green-sand mould. No Al used ..	47,300	79,300	32.0	51.5	38.5
	45,100	79,400	31.5	56.6	
Air-dried green-sand mould, 0.05 per cent. Al added	49,650	78,950	26.0	36.0	27.0
	48,900	79,400	25.0	36.6	
Moistened green-sand mould. No Al used ..	44,350	78,800	31.5	55.7	37.0
	47,700	79,200	31.5	56.0	
Moistened green-sand mould, 0.05 per cent. Al added	49,550	79,250	24.5	34.6	26.5
	50,450	80,000	25.0	35.7	

[6] G. Batty: "The Interrelationship of the Pin Hole Trouble and the Low Ductility Problem." *Trans.* Amer. Foundry Assn. (May, 1931).

aluminium and the solidification of the steel was probably not over one minute, it being cast as a 1-in. section; yet there was time for this change to take place. Had the inclusions in the metal cast in dry sand moulds existed as such before the aluminium addition, there must certainly have been insufficient time for the highly diluted aluminium to have wrought such a change. The reaction would be limited to the surface of the inclusions and could progress only as fast as the aluminium could diffuse to the inclusions. Large inclusions would have to be broken into smaller ones and the very small ones agglomerated into larger ones, for after the aluminium addition, there is considerable uniformity in size. But if one considers the non-metallics as being in solution, all the difficulties of explanation disappear. Speed of reaction is limited only by the rate of mixing and diffusion of the aluminium, and the inclusions are free to form in their natural manner without regard to the way in which they would have formed had the aluminium not been added.

A similar test was carried one step further in heat 564, as shown in Fig. 9. In this, iron ore was added 1 min. after the aluminium addition, and the steel was poured 1 min. later. Instead of the characteristic structure produced by aluminium, the inclusions are all globular and scattered except for the clusters of alumina. The alumina inclusions (which are probably aluminium silicate) are practically unchanged, and this is regarded as evidence that they, unlike the iron-manganese silicates and iron-manganese sulphides, are largely insoluble.

What Can be Done about Inclusions.

One of the puzzling things about steelmaking has been that occasional "bad" heats have been produced for which no definite reason could be assigned. They might be made in approximately the same manner and from the same material as "good" heats, and have almost the identical composition, but the bad heats seem to have an inherently inferior ductility and general stamina. These off heats seem to be sluggish and do not fill the moulds well. The so-called "over-reduced" steel[7] is an example of these off heats. In the authors' own experience, steels very close in composition and made by what seemed, at the time, to be identical practice, have been compared and have been found to vary as much as 50 per cent. in elongation and 100 per cent. in reduction of area. It has been observed that electric-furnace steel is more prone to these off heats than open-hearth steel, and that the prevalence increases rapidly with increase in carbon content. Many of these off-grade heats with low ductility have been examined and compared with better steel. Invariably the microscope revealed the condition that has already been described at length; namely, the low-ductility steels had the eutectic type of inclusions, while those of high ductility had the scattered globular type. The accusation being thus placed directly on the inclusions, the question arose as to what remedy could be applied.

If the inclusions could be eliminated, presumably most of the troubles would disappear, but at present there is no known method of accomplishing this end, and it never happens accidentally. If steel could be made sulphur-free, a large portion of the inclusions would be automatically eliminated. The fight against sulphur has already been waged for years. Vacuum melting and casting offers considerable promise for cleaner steel, but as yet is undeveloped. It is to be sincerely hoped that some day a method for producing "clean" steel will be perfected. The apparent solubility of the inclusion-forming material indicates that it is a more difficult problem than has been anticipated. In the meantime, there are the inclusions to contend with. The thought occurred to the authors that inasmuch as the inclusions occur sometimes in a benign condition, they could always be made to take this harmless form if the proper conditions were known. Accordingly, experiments were conducted to see what could be done in that direction.

In the early heats in the arc furnace with an acid hearth, it was found necessary to make a general use of aluminium in order to prevent excessive porosity in the castings. The aluminium did not always give freedom from porosity, but it did usually greatly decrease the ductility. However, there were occasional heats that despite the aluminium had very satisfactory ductility. Moreover, these ductile heats handled well, were quite fluid, and as a rule gave sound flawless castings. One of the first indications of the cause for these unusual heats was obtained when an experimental heat was made in which four times the usual quantity of iron ore was used. Contrary to some predictions, this heat was excellent in every respect, showing good ductility even though aluminium was added to the ladle in the proportion of about 1 lb. per ton of steel.

In this case, severe oxidation of the bath had been successful and had given desirable results. This was checked up and was found to be consistent. Earlier, a special test heat had been made by quite the opposite procedure. Thinking to take advantage of the electric furnace's reputed ability to maintain a neutral or reducing atmosphere, it was decided to run with the very minimum of oxidation. A charge of clean scrap was selected with a carbon content so low that no oxidation was necessary to attain the desired composition. It was melted down under a light brown translucent slag, which was practically free of ferric oxide. Here was a steel that should be all that could be wished for! It could not be gassy because it was being deoxidised continually from the beginning of the melt down! Additions of ferro-silicon and ferro-manganese were made in the furnace and a little aluminium was added to the ladle. The latter was not considered necessary, but was added merely as a precaution. This steel literally effervesced in the moulds and was so gassy that not even a test-bar could be obtained. It was also sluggish and tended to plug the nozzle. Another experiment concerned a heat of steel that had been treated with 1 lb. of aluminium per ton, put in the ladle at the time of tapping. A standard test block was poured, and then immediately afterwards, 100 lbs. was tapped into a hand ladle. While it was pouring into the hand ladle, 150 grams of iron ore was added and mixed by the agitation of the stream of metal. It was then poured into a similar test block mould. A comparison of the physical results is shown in Table III. Microscopic examination showed clearly the reasons for this difference. The steel direct from the ladle had the eutectic type of inclusion, while in the steel treated with iron ore the inclusions had somehow been transformed to the globular scattered type.

Experiments were continued in the high-frequency induction furnace. Although conditions in this furnace are somewhat different from either the open-hearth or arc electric furnace, the basic principles of steelmaking are the same in any furnace. It is not the practice to use aluminium in the steel from the induction furnace except in special heats where its effect is being studied. Even so, the ductilities varied a great deal, and it became very urgent to find out why. This was especially true with the higher carbon alloy heats where the carbon ran 0.35 per cent. or more. The fact that the trouble seemed to be in proportion to the carbon content suggested that the carbon might have an influence. Nearly all of the tests were run on higher carbon contents, the idea being that if they could be made satisfactorily the low-carbon steels would be automatically taken care of.

Certain conditions were found to be of advantage in giving high ductility to steels which ordinarily gave a large proportion of low-ductility heats. If the carbon content of the bath was kept low until very near the end of the heat, high ductility usually resulted. Recarburisation after the alloy additions was best, but the steel was apt to be gassy. Recarburisation just previous to the alloy additions worked well and gave sound steel. Adding a small amount of iron ore and allowing it just time enough to dissolve before adding the deoxidiser gave very good results.

Adding the ferro-manganese ahead of the ferro-silicon showed advantage over adding them together or with the ferro-silicon first. Using mixed alloys, like silico-manganese of any ratio, was better than ferro-manganese and ferro-silicon. One annoying mystery apparently was cleared up when it was found that a variation in the temperature of the metal at the time of deoxidation often made a notable difference in the inclusions and resultant ductility. If the metal was very hot just before the deoxidisers were added, it was ductile; if rather cool, the ductility was low even though the temperature was increased afterwards. An example of this is shown in heats 498 and 499, the composition and properties of which were as follows:—

TABLE III.—*Results on Aluminium-treated Steel with and without Iron Ore Added.*

	Y.P. Tons per sq. in.	M.S. Tons per sq. in.	E. in 2 in., per cent.	R.A. per cent.	Fracture.
Direct from ladle	2.29	3.56	23	25.8	Woody
Treated with iron ore	2.12	3.51	37	51.1	½ cup

Heat No.	Composition, per cent. C	Si	Mn	S	P	Y.P. tons per sq. in.	M.S. tons per sq. in.	E. in per cent. 2 in.	R.A. per cent.	Izod impact, ft.-lb.
498	0.636	0.40	1.41	0.034	0.015	3.23	6.07	14.0	22.3	4.5
499	0.624	0.44	1.33	0.031	0.015	3.19	5.92	18.0	36.0	6.0

Heat 498 was kept cool until after the alloy additions, when it was heated to a good pouring temperature. Heat 499 attained its maximum temperature just before the alloy additions. Other conditions were as nearly as possible the same. Both were given a double normalising treatment as 945 deg. C. for the first and 815 deg. C. for the second treatment.

General Theory.

Although the data collected are much too meagre to allow a detailed explanation of the phenomena that occur in deoxidation and inclusion formation, certain factors are so consistent and obvious that a tentative theory can be advanced. All of the facts so far cited point definitely to the great importance of iron and manganese oxides in the inclusions. Iron oxide, undoubtedly, is the more important of the two. The addition of aluminium to steel tends to eliminate the iron oxide. A low-carbon steel will be higher in iron oxide before deoxidation than a high-carbon steel. Adding iron oxide just previous to deoxidation causes the steel to contain much more iron oxide than equilibrium conditions would permit. Adding the manganese before the silicon causes the formation of manganese oxide, which in turn apparently causes the inclusions to be richer in basic oxides. In-

[7] J. V. McCrae, R. L. Dowdell and L. Jordan: "A Study of the So-called 'Over-Reduced' Condition in Molten Steel." U.S. Bur. Stds. *Jnl. of Research* (November, 1930).

creasing the temperature previous to deoxidation causes the steel to carry more oxygen for the same carbon content.

In the ductile steels, there are the globular and the angular or crystalline inclusions. The globular inclusions obviously were precipitated as liquids in a liquid medium; in other words, before the steel solidified. They retain their globular shape either because they solidified after the steel and were forced to retain their shape or because they did not crystallise but cooled to a glass. The angular inclusions, such as are shown in Fig. 8, were precipitated as either liquid or solid in a liquid medium, but, in any case, solidified as a crystalline material while the steel was still molten and, therefore, were able to assume their natural crystal shape. This type of inclusion is comparatively rare and has only been found in steels containing well over 1 per cent. of manganese, and then only when the ductility is somewhat low. The explanation advanced for this is that in steels of this manganese content the sulphide consists principally of manganese sulphide, which has a melting point above that of steel. These sulphides, therefore, will crystallise before the steel freezes unless they are sufficient iron and manganese oxides present as such or as silicates to flux them and reduce the melting point.

The globular inclusions occur either as dark coloured silicates, light coloured sulphides, or as duplex inclusions containing both. Some excellent examples of the duplex inclusions are shown in Fig. 11. One large globule contains a large proportion of silicate with a small amount of sulphide, while another large one consists mainly of sulphide. Iron-manganese silicates and iron-manganese sulphides are miscible in the molten condition but separate on solidification. It is reasonable to suppose, however, that the sulphide is a saturated solid solution of iron-manganese silicate, while the silicate is a saturated solid solution of sulphide.

In the steels of low ductility, the inclusions that form part of the eutectic are of one constituent, which appears to be sulphide. The clusters of small dustlike particles, which are usually referred to as alumina, are believed to be aluminium silicate. There is SiO_2 somewhere, and if it is not with the sulphides, it must be with the alumina.

But why do the sulphides sometimes form globular inclusions, which are comparatively harmless to steel, and at other times form a network enveloping the primary crystals to the great detriment of ductility? It has been demonstrated that the quantity of iron oxide and manganese oxide present is the influence that controls the form that the sulphides will take. If there is sufficient iron oxide present, the sulphides will precipitate as the steel begins to freeze, while in the comparative absence of iron oxide the solubility of the sulphides is increased to such an extent that they separate only as a eutectic with the last steel to freeze.

When aluminium is added to steel, it first reduces iron oxide. If it reduces enough of it, the sulphide inclusions will be changed from the globular to the eutectic type, and the globular iron-manganese silicates to the refractory aluminium silicates. If there is a large quantity of iron oxide present, or only a small addition of aluminium is made, enough iron oxide will remain to precipitate the sulphides and the steel will not suffer in ductility. If iron oxide is added to steel which has already been treated with sufficient aluminium to change the sulphides to the eutectic type, the sulphides again take the globular shape, as shown in Fig. 9. But in such a case, the iron-manganese silicates are almost absent.

As may be seen in Fig. 7, a powerful deoxidiser, such as calcium silicide, has the same tendency as aluminium to cause low ductility through its indirect effect on the sulphides. A high-carbon content has a like tendency. In short, any condition that will lower the iron oxide content sufficiently will set the stage for low ductility. The obvious remedy is to maintain a proper amount of iron oxide by any method that will attain this end. Such a remedy has worked successfully in repeated tests.

Summary.

(1) There is a direct relationship between the character and distribution of inclusions in cast steel and the ductility of such steels.

(2) The globular type of inclusion scattered haphazardly through the steel has the minimum effect on the physical properties.

(3) The eutectic type which forms a network in the steel causes the steel to rupture after slight plastic flow with resultant low ductility.

(4) The variations in quantity of inclusions ordinarily found in steel have almost no effect on the physical properties.

(5) The normal inclusion-forming material of steel is soluble in the molten state and precipitates as inclusions at the time of solidification.

(6) If the iron oxide content of the steel is high, the inclusions will precipitate at the beginning of solidification and will exist as globules of silicates and sulphides, and the steel will have good ductility.

(7) If the iron oxide content of the steel is too low, the solubility of the sulphides is increased to such an extent that they precipitate as a eutectic with the last steel to freeze. The ductility of such steel will be low.

Acknowledgment.

The authors wish to express their appreciation for the co-operation, encouragement and kindly criticism of Mr. W. C. Hamilton, Director of Research, and to Mr. E. H. Burkart, who actively participated in the collection of data.

Automatically-Charged Blast-Furnace Plant.

THE INSTALLATION AT STANTON.

During the annual meeting of the Society of Chemical Industry, held at Nottingham in July, an opportunity was afforded of inspecting the plant of the Stanton Ironworks Company, Limited, whose automatic blast-furnace plant is one of particular interest. The Stanton plant for the production of Spun-iron pipes is claimed to be the largest in existence for this purpose.

The extent to which automatic devices have been applied to the blast furnaces—which have an output of 1,000 tons of pig-iron per week each—is astonishing, even in these days of accomplishment. The ore (ironstone), coke and limestone are stored in bunkers. The materials are fed into scale cars running beneath the bunkers; in these they are weighed automatically, and then are delivered to skips which convey them to the top of the furnace. At the top of each furnace there is a distributor, containing four sections, and this works round until all four sections are full. It then tips into a bell. The little bell opens and drops the material into the big bell beneath it; the little bell then closes, and subsequently the big bell opens and discharges the material into the furnace. This closing of the little bell before opening the large one is necessary in order to prevent the escape of gas from the top of the furnace.

The gases from the top of the furnace are utilised at the boilers for raising steam, and for heating the stoves through which the blast passes on its way from the blast engines to the furnace. The blast is heated to a temperature of 1,150 deg. Fah., and the blowing units are turbine blowers. The turbines work at a speed of 3,500 r.p.m., and, with the blowers, supply air at a pressure of 10 lbs. per sq. in.

The ores come from Leicestershire and Lincolnshire, and contain approximately 30 per cent. of iron; they are hydrated iron oxide. A certain percentage of the ore burden is made of the raw stone, and together with this there is a calcined ironstone, this latter being calcined at the ironstone quarries. The calcining increases the iron content from 30 to 43 or 44 per cent.; it eliminates excess water and carbon dioxide, and, naturally, freightage per unit of iron content is less than that on the raw stone.

The furnaces are tapped every six hours, and the molten iron is run into moulds made in sand

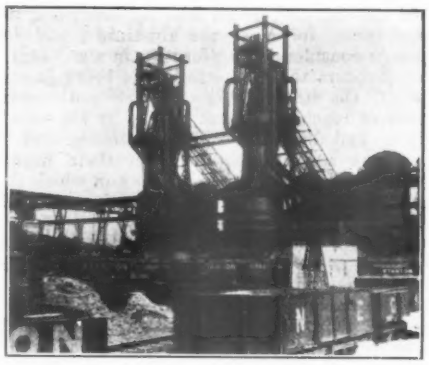


Fig. 1.—Stanton Ironworks Furnaces. Automatically charged, with output of 1,000 tons per week.

in front of the furnaces. The slag from the furnaces is run into large steel ladles, each holding about 4 tons. This slag is allowed to cool for about 6 hrs. until set, and is then tipped out and allowed to cool for a further day. Then it is broken by hand into lumps, crushed, passed through screens, tarred, and sold as tarred slag for road repairs.

At Stanton there are five furnaces, of which at present two are in blast and two are being relined; these latter will be put into commission in the course of a further six weeks. At another

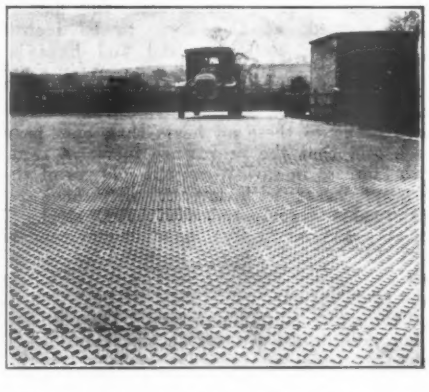


Fig. 2.—Stanton Iron Road. Laid on a concrete foundation and grouted with bitumen. It is non-skidding and can be easily taken up for repairs and relaid at low cost.

works, at Holwell, near Melton Mowbray, there are five more furnaces, but they are not automatically charged.

An interesting development with which the company is concerned is that of supplying cast-iron setts for road construction. These are of rectangular shape, having a non-skid pattern. They have the advantages of low cost, they can be laid easily on concrete foundations, and are grouted with bitumen. A road constructed with such setts has been in service at Bromley for some time, and there is another under construction at Barnsley; they are also being used in Sheffield and Birmingham.

Camber.

A PRACTICAL DISCUSSION.

DISCUSSION.

Mr. Longden's Paper*, as was expected, resulted in a practical discussion of great utility. It was opened by Mr. A. Sutcliffe, who said he welcomed the Paper as being the most practical that had been submitted to the Institute for many years. He could not recall any other Paper which had mentioned camber since that which was read by Mr. H. Jowett before the Burnley Branch in 1924 or 1925. With regard to the bed mentioned in the Paper, the camber allowed was just what he would have allowed. The difficulty was that orders for lathe beds usually comprised only one of two castings to a given length, so that one had to decide upon the allowance to be made for almost every individual casting. He asked if Mr. Longden put the camber strips in the bed of the floor, or had he a full pattern with the camber in it; in most of the foundries in which he had made this class of work, he had only a short length of a pattern and sometimes it required shifting three times to make a casting 30 ft. long, such as planing-machine tables, side planers and lathe beds different in width or length. When making these castings the camber was mostly always obtained from the straight edges in the bed of the foundry floor. He suggested that the designer did not give enough allowance for machining these kinds of casting and that they had no idea of camber. Mr. Jowett, Mr. Longden and the speaker were all of opinion that camber experience is obtained by practice only. This is where the chart will be of great benefit with regard to the castings referred to in Fig. 2 of the Paper, the back being the thickest part of this casting and being the last to set, therefore it pulls out the ends as stated.

Mr. Sutcliffe then drew a series of sketches on the blackboard to illustrate his points. Fig. A

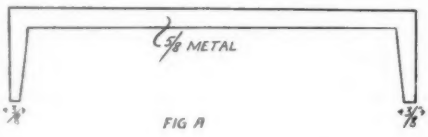


FIG A

showed a drying machine through the trough section, a type of casting required in lengths of to a maximum of 14 ft. Sometimes both ends are cast integrally and sometimes at one end only, because the metal is at the top side of the casting, the pattern is bedded down at both ends, varying with the length of the required casting. Fig. B shows a weaving-loom casting

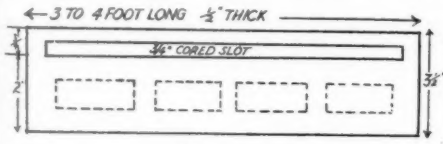


FIG B

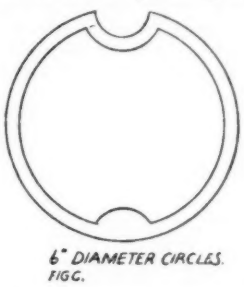
and resembles somewhat Fig. 2 of the Paper. Most of the mass of the metal is on one side, and although the pattern is embossed where shown by dotted lines, the casting often cracks at the point A[x], but only at one end. If the casting be gated, utilising light, thin grey-sprey runners, this will allow of the casting cooling more equally.

Fig. C shows loom roller about 12 ft. long carrying a ½-in. metal section of which the speaker had had considerable experience, and encountered a certain amount of trouble until he added the extra metal shown to be opposite the groove. It was found to prevent warping even when using a camberless machine pattern.

Fig. D represents a trough-like casting of which he had recently made two from the full pattern. As it was difficult to produce adequate camber in the pattern by weighting, the job was cast without camber, but the base was bared where the T slots are shown. The sand was also removed from the slots, and castings true to pattern were produced.

Specific Gravity of Solid and Liquid Iron.

The President drew attention to the statement in the Paper reading "It is generally assumed that the specific gravity of cold grey iron is greater than that of molten iron. If this be so, why does cold grey iron float on a bath of molten metal of grey iron composition? Is this not conclusive evidence that cold grey iron is of lower specific gravity than molten metal of a similar volume and composition?" He did not contest that, because he did not know; he would rather ask—in the Irish way of answering by putting another question—Was the casting smaller or larger than the pattern which had been used? He did not think the after-casting expansion of grey iron sufficient to reduce the specific gravity of the cold metal to below that of the molten. Might not the floating of the cold metal be due to the surface tension of the molten metal? In this connection he mentioned the experiment in which a needle, after having been lightly greased by the finger, was placed on tissue paper and then placed on the surface of water, leaving the paper to sink, the needle being left floating. One would not say, however, that the needle was of lower specific gravity than the water. It was a result of the surface tension of the water. Again, if one placed cold grey iron on the top of molten metal there might be, between the clean molten metal and the clean metallic part of the cold iron, quite a quantity of other material of distinctly lower specific gravity, which would be enveloped by the molten iron and help the buoyancy.



FIGC.

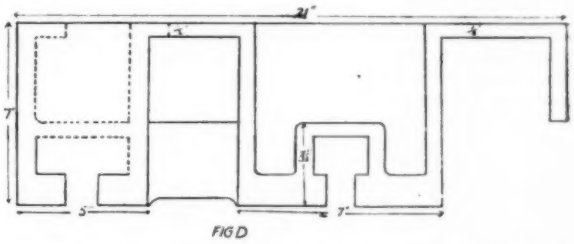


FIG D

With regard to the last experiment mentioned at the end of the Paper, he had not had time to study it seriously, but he gathered that the pith of the experiment was that the thinner bars contracted more than the larger. He would be inclined to ascertain the combined carbon and the graphitic in the two cases, because if there were more graphitic in the thicker one its average specific gravity was bound to be lower than that of the thinner one. The one which had the greater graphitic content would contract the less.

Dr. A. B. Everest asked if it had not been borne out in practice that an iron with a higher combined carbon content would have a greater contraction both before and after solidification.

The President said he was speaking of bars all of which had a similar total carbon content.

Dr. Everest agreed, but pointed out that in a casting with thin and thick sections the thin sections would contract more than the thick, the point being that they had a higher combined carbon content, but the total composition was the same. That might explain some of the facts which Mr. Longden had referred to.

The President said that that was what he meant. Was it not purely that effect?

Mr. F. Hudson said that he also had been particularly interested in the statement that the specific gravity of the cold grey iron was greater than that of molten iron, but the more he had thought about it the more he had got into difficulties. The actual specific gravity of molten cast iron was determined individually by the late Dr. Moldenke and Dr. Benedicks at different times. The figure given by Dr. Moldenke was 6.65, and that given by Dr. Benedicks was 6.66. The specific gravity of cold cast iron was 6.8 for the grey iron and 7.8 for the white iron, which, according to the text-books, again assumed that molten iron had a lower specific gravity than solid iron, and, therefore, solid iron should not float on molten iron. But we all knew that it did float on molten iron, and it occurred to him that perhaps the difference of specific gravity as between the grey and white iron had something to do with the matter. Grey iron was not so heavy as white iron. In his view, the difference lay in the fact that the carbon was in a different form. The more combined carbon there was, the heavier the iron. When iron was melted, the carbon was supposed to exist in the combined form. Taking that line or argument, if cold grey iron had a specific gravity of 6.8, then, when it was melted, inasmuch as the carbon was in the combined form, the iron should be heavier. This seemed to be another matter in respect of which the text-books were at fault.

The President asked whether, in connection with the last statement, allowance was made for the expansion due to heat?

Mr. Hudson said it was. One would have to allow for that, and that was another point which might be considered as well. He would like Mr. Longden's views on the matter.

Mr. John A. Smeeton congratulated Mr. Longden upon having endeavoured to put before the Conference in a concrete form the results of his experience concerning camber, especially in connection with the heavier type of casting. In making the heavier types of beds, which in many instances had to be made from short pieces of pattern, it was very difficult to decide how much camber should be allowed, in say, a 6-ft. length, and how much in a 36-ft. length, because there was some slight difference in the resultant structure in the longer one as compared with the shorter one. The records in the Paper would be of very great use to those controlling foundries generally. A point to be borne in mind in relation to this Paper was that the moulder was simply given the job to do, but the foreman and the manager and the chemist controlled the iron to be used, and in 99 cases out of 100 the moulder had no knowledge or control of the iron to be used.

Usually in foundries making light castings, the patterns used were made of iron. A straight wood pattern was made first in order to find out how much camber was required. After the camber had been decided upon, a master pattern

* Foundry Trade Journal, June 30, Page 395, Vol. 46.

was made, with double the amount of camber, the iron pattern was made from that, and the other kept at one side in case of breakage. Those who were concerned with the making of textile-machinery castings must have some extensive data which might be handed on to Mr. Longden to add to his excellent Paper. The same remarks applied to the makers of stove-grate castings. In many cases the addition of a small lug would alter the shape of the casting entirely from the first original camber that was put into it. Thus the whole question of camber was one which required very deep thought and careful consideration, so that useful figures might be produced for future use.

Mr. B. Hird, in complimenting Mr. Longden on his courage in tackling the problem of camber, said that it was one which, like the poor, was always with us, and in the past founders had had to make the best guess they could, and try it. It was a great responsibility to decide how much or in which way camber should be put on. The patternmaker very seldom took the responsibility for camber, unless the patterns had been made before, and the responsibility was usually left to the foundrymen on the floor. With regard to contraction, he asked for Mr. Longden's opinion of the relative tensile stress, to resist shrinkage, when metal was solidifying, between two points 2 in. apart and two points 4 in apart. Would there be a greater strain at the points 4 in. apart than at the points which were only 2 in. apart.

Mr. J. E. Fletcher (Consultant, British Cast Iron Research Association) said that although there was no doubt, as had been mentioned, that the difference between the graphitic-carbon percentage in the thick and thin bars of cast iron must have something to do with this distortion, yet the curious thing was that when one was dealing with a similar problem in steel one had sometimes the same camber troubles to deal with, and it was a question then, obviously, of a difference in cooling. If all other conditions were the same, there was the graphitic-carbon problem to deal with. He recalled an experience which had occurred some few years ago in connection with the making of pump rods about 64 ft. long, in steel. They were of the old-fashioned cross-section pattern, with the two big ends, one for the beam end and the other for the pump-connecting end. The castings weighed about 8 or 9 tons each and they were to be used for deep-well pumping. There had been some hesitation as to the manner in which they should be cast. First, there was a combined runner and riser at each end of the casting, and as soon as the castings were made, one had to release the sand in front of the risers lest trouble from local cracking should occur. Although that was done, the first casting had broken straight through the centre section. There was no riser on the centre of the casting, and they had relied on the risers and heads at each end. The curious thing was that when measurements were made it was found that, whilst the contraction overall was about 10 in., the first casting had contracted equally from both ends towards the centre; there was a gap of 5 in. at each end of the casting. The next casting was run from only one end, and all the rest of the castings afterwards were successfully made in that way. Those responsible had run the castings as quickly as they dared, and all the contraction then was in the direction of the runner and riser at the one end, and there was the complete 10 in. of contraction gap at the end furthest from the runner and riser.

He had made many attempts to arrive at some method of estimating what the camber should be for a casting, but he was afraid he had had to revert to the old practical idea of making one first. A good many people would say that it became almost second nature, after one had experienced a number of accidents to avoid similar accidents in the future, but he was still in that unhappy position, and he was not able scientifically and accurately to determine what the camber should be when first applying a practical test.

In a further written contribution, Mr. Fletcher said that in his experience with the casting of both grey-iron and steel propellers of large size the distortion trouble, due to the further twisting of the blades during cooling had to be reckoned with. The expected "pitch" of the blades was not always obtained, correction in the striking-up templets for the helical surfaces having to be made to obviate this defect. The amount of correction needed could not be theoretically estimated, and only practical experience was the guide.

He had also observed camber or warping defects in long white-iron castings of unequal thickness, and here the warping difficulty was only overcome by altering the method of gating. In such cases the tendency to camber generally resulted in fracture during cooling and was influenced by the composition of the white iron.

Again, the tendency to warp or camber was seen in the forging of both steel and iron U-shaped shackles. Here the smith had to water-spray or air-blast cool the outside of the curved surface whilst bending in the hot condition so as to prevent the opening-out of the shackle during cooling and to keep the bar section from distortion.

He (Mr. Fletcher) contended that whilst in grey iron castings the difference in combined carbon contents in the thin and thick walls of a casting influences the amount and rate of contraction and is one of the main causes of distortion or camber, the different rates of cooling of the thin and thick sections from the molten condition and through the recalescence range govern the combined carbon content, but this in turn is dependent upon the analysis of the metal. Differential rates of cooling in any casting, he contended, were primarily due to defective design, and there were few more difficult problems than those of designing castings which, owing to their contour, were naturally liable to distortion during cooling from the molten state.

Author's Reply.

Mr. Longden replied to the discussion. Referring to the chart in Fig. 1, he said he should have stated that the figures on the right of the chart showed the camber required. With that addition, the chart should be read fairly easily. For instance, if one had to make a bedplate 24 ft. long and with general 1-in. section, then by following the line up vertically and again horizontally one came to a camber allowance of $\frac{1}{2}$ in., if the depth of the bedplate approximated 20 in. If the depth were about 30 in., the camber requirement decreased to approximately $\frac{1}{4}$ in., and at 40 in. depth the camber allowance was about $\frac{1}{8}$ in. He had experienced the utmost difficulty in correlating the width of casting on that chart. He had had visions of constructing several other charts, but he would have needed a large number of charts in order to explain the matter as fully as he would have liked to. The chart in Fig. 1 was quite good so far as the class of work described in the Paper was concerned, and would be helpful in the making of castings of a similar nature and generally, if the generalisations on camber, as set out in the Paper, were taken account of in reading the chart. It was stated, for instance, in the generalisations, that camber allowance, other dimensions remaining constant, increased with increase in length of casting. The chart followed that out. Again, that camber allowance increased with reduction in metal section was borne out by the tests outlined in the Paper, and also by the remarks of Dr. Everest, that the thinner sections contracted more than the thicker, and consequently there was greater distortion.

No reference to side camber was made in the Paper. This matter was far too involved for him to attempt at the moment, and he had left it out of account entirely for the time being.

Discussing the setting of patterns in the mould to give the necessary camber to overcome distortion, he said that certainly one should always lay the camber strips in the bed. He imagined that Mr. Sutcliffe had an idea that in some cases the casting was bared, but he would warn foundrymen not to attempt to bare a substantial casting. His attention had been called to a heavy bedplate, weighing something like 20 tons, which had cracked. The founders had been unable to determine the camber, and had decided to bare underneath the bottom of the casting; the result was a fractured casting. So that if one had only one section of a pattern to make a rather long casting from, the setting of the full-length bed obviated all the possible troubles; it was only a matter of moving the section of pattern as required along the arranged bed until the required length had been obtained.

Referring to his remarks in connection with chilled rolls, he said that several rolls were made experimentally. Such experiments well repaid their cost. The results of his experiments had been rather startling to him, because he had always imagined chilled rolls being fed over hours, and he had fully expected, in spite of his experiments on common iron, to find a cavity at the top end, as cast. But there was none there at all.

Commenting on the references made to his statement concerning the specific gravity of grey cast iron, he had rather thrown out this obvious fact as a bait to our eminent metallurgists, and had expected them strongly to debate the phenomena, but they had not done so. The fact remained, that if one pushed a piece of cold or warm cast iron under the surface of molten iron it would bob up to the surface again every time. He had been careful to state that the metal, when cold, occupied a smaller volume than when hot or molten, and that cold grey iron was of lower specific gravity than molten iron of *similar volume and composition*. In his opinion, mass in grey iron had a greater effect on contraction than had the actual composition, as instanced by experiments on bars of different section. Mr. Hudson had replied to the points raised on this matter, and he was indebted to Mr. Hudson for his exposition.

With regard to the possible difference as between two sections of metal between points 2 in. apart and points 4 in. apart, the tensile strength would be less on the longer section than on the shorter.

Finally, referring to Mr. Fletcher's remarks, he imagined that in steel even the friction resistance of the flat face of a mould would cause tears and cracks occasionally.

Mr. J. G. Pearce wrote that Mr. Longden's Paper was extremely interesting and would be of very great practical value. No question was of greater importance to the founder than shrinkage and contraction. The very first investigation ever undertaken by the Cast Iron Research Association was on this question, and a casting was specially designed to show the defects in a maximum degree for the purpose of examination. Great difficulty, however, was experienced in finding foundries which could produce a casting bad enough to show the defects desired, in spite of the design. Later it was found necessary to study more fully the effects of various elements in cast iron acting conjointly, and the more recent discovery of the effect of melting conditions on the properties of the casting fills the gap in our knowledge which was required before shrinkage and contraction could be investigated on a proper basis. A general investigation on shrinkage and contraction was now contemplated by the Association.

The Governments of the Union of South Africa and Japan have signed a contract for the supply of 30,000 tons of South African scrap iron to Japan, according to a message from Durban

Combustion of Pulverised Coal in Metallurgical Furnaces.

By Dr. Peter M. MacNair.

The idea of using rotary furnaces for smelting operations is by no means of recent date, and the suggestion to use pulverised coal as an economical and efficient fuel has been mooted for many years. It is only within recent times, however, that the conditions for the satisfactory burning of pulverised coal have been perfected to such an extent as to realise the commercial possibilities in the manufacture of such material as cast iron. Modern ideas on combustion of pulverised fuel may be briefly discussed under the following headings:—(1) Unit as against central system of pulverising; (2) grinding fineness; (3) mixing of fuel and air; (4) preheating coal and air; (5) rapid ignition; (6) heat release per unit of volume, and (7) bituminous as compared with anthracite coal.

It is not so long ago that the unreliable nature of the pulveriser made it advisable to install the expensive bin and feeder system whose main object was to store a supply of finely-ground material against the possible breakdown of the pulverising machine. To-day the unit type has reached such a high degree of efficiency and reliability that it is becoming more widely adopted to the almost entire exclusion of the older method. In unit-firing, the coal feed is under very accurate control whereas with screw feed from a bin the quantity discharged is dependent on the efficiency of de-aeration. The fact that the screw is working at a constant speed does not necessarily mean a constant feed of coal as account must be taken of the relative air-quantity entangled with the fine coal. Efficiency of de-aeration may cause the coal feed to vary up to 20 per cent. of normal. With bin storage it is also important to install a good drier as the passage through the bin and conveyor screw tends to make the small particles clog and aggregate, thus producing the troubles associated with coarse grinding. With the unit system any moisture present in the coal passes to the burner. Owing to its inert nature there is a consequent lowering of the flame temperature, but this is not of serious moment provided the moisture does not exceed about 7 per cent. Moisture also tends to decrease the efficiency of pulverisation, but this difficulty is overcome by passing the coal to the unit-type mill with a stream of preheated air which drives off the water as steam, thus allowing the grinding elements of the mill to get the optimum effect by impacting on dry friable coal particles.

Increase in grinding fineness has been one of the primary causes for the more efficient use of pulverised coal. For metallurgical work it is of great importance. In this type of firing it is essential to get a thorough mixing of the combustible matter with the combusting oxygen, as the speed of firing and economic volume available are such that combustion has to be completed in less than a maximum of 3 sec. The necessity for fine grinding arises from the necessity of exposing as large an area as possible to the air supply. In a heterogeneous reaction between solid and gas the speed of reaction is directly proportional to the active surface of the solid exposed. Table I shows how the surface area of 1 lb. of coal increases with degree of fineness. The usual specification to-day is that from 75 to 90 per cent. should pass through 200 British mesh screen. This, of course, does not give a distinct idea of the size of the finest particles, but the difficulty of making accurate sieves of finer mesh places a severe limitation on their use. It does, however, ensure that the majority of the particles are of such a size as to permit of their burning in the time available. The large particles are less likely to be completely burned inside the furnace and to that extent cause a decrease in efficiency of the coal. It is therefore advisable that an upper limit should be placed on the fineness and there should also be a stipuluation such as no residue left on, say, 60-mesh screen.

Table I.—*Surface Area for Varying Grinding Fineness.*

Average Dia. of Particles.		Surface Area of 1 lb. Coal Dust in sq. ft.
Mesh.	Size in ins.	
—	0.001	650
—	0.002	325
200	0.003	215
150	0.004	162
—	0.005	130
100	0.006	108
—	0.007	93
60	0.008	81
—	0.009	72
—	0.010	65
50	0.011	59
40	0.015	45
30	0.020	32

Fine grinding gives a larger area for reaction, but design of burner can give equally valuable assistance by increasing the active area. As each molecule of oxygen gets to the carbon of the coal it forms a molecule of carbon dioxide, which has to be dissipated from the surface before another oxygen molecule can reach it to react. When burning a constant quantity of coal in a given volume of combustion chamber, the time taken for a coal particle to pass through is constant. However, with turbulent flow from the burner, the number of collisions between oxygen and coal is increased, with consequent quicker burning, shortening of the flame and production of higher temperatures.

Various types of burner have been designed with the object of imparting a spiral flow to the mixture just before discharge, as it is an obvious advantage to increase the turbulence within the furnace. It is not sufficient to have a thorough mixing before the burner; it is more important to have this swirling motion at the point of ignition and subsequently. By creating a vortex action, centrifugal force tends to expel the fuel particle from its own atmosphere, and thus speed up the contact of the coal particle with fresh oxygen. This relative velocity effect between solid coal and gas increases as the square of the diameter of the particle. Thus the coarse particle, which, owing to its mass, takes the longest time to burn completely, has the optimum aerodynamical conditions, giving it the highest relative velocity. In this way rapid and complete combustion of all particles is assisted.

The most satisfactory way to produce this vortex action is to supply powdered fuel in a primary stream with the burner so designed as to give the necessary swirl. The primary stream contains only a portion of the total air required for combustion, while the remainder is added inside the furnace from a secondary supply. This double air supply has the advantage of giving a large relative air to coal velocity, with consequent quicker removal of reaction products, as compared with a burner where the total air and fuel are mixed some distance prior to reaching the burner.

In Fig. 1 the time taken for complete combustion with the same coal and air supply, but using different burners, is illustrated. The thick line shows the rapid completion of combustion with a swirling and mixing burner. In the dotted line there is shown the other extreme, stream-line combustion with only 15 per cent. of the air supplied with the fuel and the balance induced round the burner nozzle.

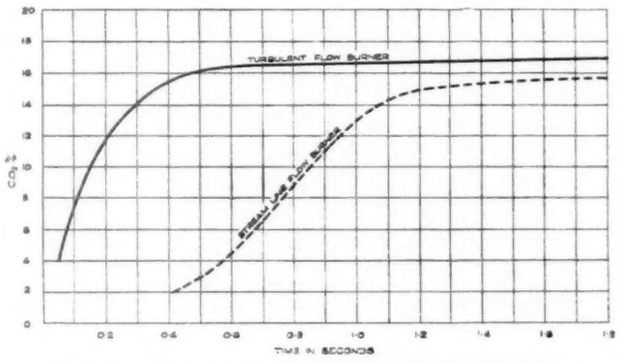


Fig. 1.—Time for Combustion of Pulverised Fuel.

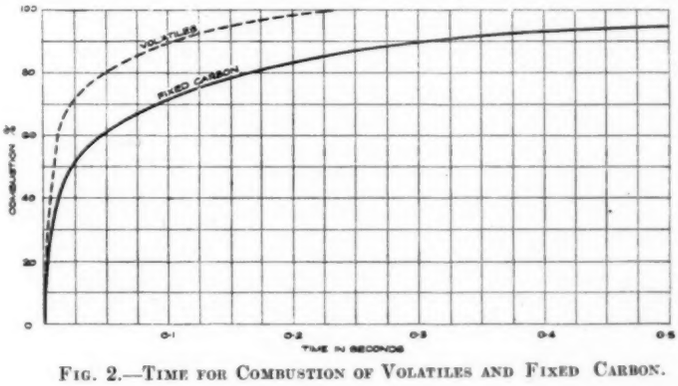


Fig. 2.—Time for Combustion of Volatiles and Fixed Carbon.

Secondary Air Temperature.

There is no need to emphasise the advantages of preheated air and fuel. Care must be exercised, however, that the latter does not reach a temperature approaching its ignition point before arriving at the burner, otherwise combustion would take place in the ducts. With bituminous coal the ignition temperature is about 400 deg. C., but with anthracite the air and fine coal may reach 500 deg. C. without undue risks. The use of a secondary air stream whose advantage in producing turbulence has already been described has an additional value here. As the secondary stream of air does not come in contact with the fuel till the combustion zone is reached it can be preheated to any temperature conveniently available. The maximum value of preheated air and fuel, as far as the time factor is concerned, is to hasten ignition. Once combustion has started, the rise in temperature is so rapid that the extra heat has not got such a pronounced effect, more especially

with volatile coals. A more important aspect of highly-preheated air is the extra input of thermal units giving much higher flame-temperatures.

The shortening of the ignition time has been tackled from another aspect which may have greater developments in the future. The rate of ignition is dependent on the rapidity of transfer of heat from the already hot surfaces to the incoming mixture. This will be quicker according as there is a smaller quantity of air used, because of the smaller weight required to be heated to the necessary temperature. The primary air-coal stream cannot be heated to the ignition temperature, but it should reach a temperature as close to it as possible, and only the minimum quantity of air, required to carry the coal in suspension, used. At the burner-tip this is mixed with just sufficient highly-preheated air to raise the average temperature of the mixture to the ignition point. Finally the remainder of the air is added as a tertiary stream and preferably some time after ignition has taken place.

Volume for Combustion.

The above factors deal more particularly with the conditions for satisfactory combustion of pulverised coal, but there is an equally important factor in the volume of furnace available in which combustion may take place. Neglect of this feature, in converting gas- or coal-fired furnaces to pulverised-fuel firing, has been the cause of much disappointment. Furnace-design is bound up with the heat-release per unit of volume or the calorific intensity. When a steady temperature has been reached the heat lost by radiation, etc., just balances the heat gained by combustion. It is this radiation to surrounding surfaces which lowers actual flame-temperatures so far from theoretical calculated values. It also accounts for the still lower flame-temperatures at the start of a melt as compared with those obtained when the furnace is in top heat. By using forced-draft and methods for promoting the more rapid combustion of coal, the heat per lb. of coal is not increased except in so far as there is an increase of heat-input by using preheated air. However, the rate of production of heat increases proportionately faster than the radiation loss, hence a higher flame temperature is possible. This greater intensity of heat produces more rapid melting and efficient use of fuel. It has an upper limit, however, determined by the resistance of the refractory to breakdown. The higher temperature of the inside, combined with lower radiation, produces a steeper gradient across the refractory lining, with consequent increase in the inside temperature. This leads to melting of the refractory. Experiments have been conducted on this heat-release per unit of volume, and the maximum values are known for several refractory materials, so allowing for a satisfactory determination of the best furnace sizes for given rates of firing. When the furnace volume is too great, the heat-utilisation is not so efficient.

Anthracite and Bituminous Coal Compared.

Finally, a few words may be said about anthracite as compared with bituminous coal for pulverised-fuel firing. Anthracite has a higher calorific value, but owing to the extra air required for combustion and the larger volume of products formed, the theoretical and practical flame temperatures reached are only slightly higher. When burned on a grate, anthracite gives a short flame and an intense local heat due to the low volatiles. The characteristics of higher ignition temperature and slow burning due to the difficulties of getting oxygen to the central portions owings to its solid nature are of importance when burning anthracite in pulverised form. Under the same conditions it takes longer to ignite and completely burn. These troubles are overcome to a certain extent at a cost by using finer grinding, which gives a larger area. Whereas with bituminous fuel it is usual to specify 75 to 80 per cent. through 200-mesh screen, it is more usual to find 90 per cent. for anthracite. It is much more difficult to get a high heat-release with anthracite, and the complete combustion zone is more extended. The flame due to the volatile matter, is, of course, shorter under similar conditions of burner nozzle, due to their much smaller amount, but this must not be confused with the more important aspect of the completion of combustion and generation of maximum heat in a given space.

Fig. 2 shows another point of importance relative to the burning of bituminous coal in pulverised form. In the case illustrated, after ignition has started there is a rapid elimination of volatile matter, so that in 0.02 seconds almost 70 per cent. has been burned and all has been removed in 0.22 seconds. This evolution of volatiles splits up the particle still further and forms coke, which swells and offers a larger area for combustion. There is thus a rapid combustion of the fixed carbon and 50 per cent. is burned in the first 0.02 seconds. After that the rate slows off, and at the end of 0.5 seconds there is still 5 per cent. uncombusted. With anthracite there is not the same splitting and coking action, and the effect is that the bituminous coal gives a shorter and more intense flame.

Paris International Foundry Congress.

In connection with the International Foundry Congress, to be held at Paris in September, the following Papers are to be presented:—

"Some Practical Considerations for Improvement of Soundness in Aluminium Alloy Castings," by Mr. H. J. Rowe and Mr. E. M. Gingerich (official American Exchange Paper).

"Some Causes of Defects in Aluminium Alloy Castings," by Dr. D. Hanson (British Exchange Paper).

"Some Notes on the Study of Expansion of Sand Moulds and Cores," by Mr. J. Varlet (official Belgian Exchange Paper).

"Oil Core Sands," by Mr. Doskocil (Czecho-Slovakian Exchange Paper).

"Strickling," by Mr. Fabre.

"Bronze Furnaces," by Mr. Dennery.

"Hydraulic Cement in Foundry Practice," by Mr. Louis Maillard.

"Metallic Cementation and Possibilities of its Utilisation in Foundry Practice," by Mr. Laissus.

"Study in Mechanism of Corrosion of Grey Iron by Acids," by Messrs. Girardet and Tsou-Ren-Kou.

"Desulphurisation of Cast Iron: Experiments on Desulphurisation by 'Solway' Soda Ash with or without Additions," by Mr. Girardet and Mr. Lelièvre.

"Production of High-Quality Cast Irons by Superheating and Refining in the Low-Frequency Induction Furnace," by Mr. Levasseur.

"Considerations on the Quality and Control of Metal in Manufacturing Steel Castings by the Basic Open-Hearth Furnace," by Mr. Roger.

"Study of Cupola-Melted Cast Irons with Low and very Low Carbon Content," by Mr. G. Delbart and Mr. Lecœuvre.

"Quantity Production of Cores without Reinforcements with Moulding Machines," by Mr. Biry.

"Mechanical Testing of Cast Iron," by Mr. Portevin.

"Applications of Acid-lined Electric Furnaces in the Steel Foundry," by Mr. Lemoine.

"Technical Factors of Instability peculiar to Over Specialised Foundries," by Mr. De Fleury.

"Aluminium Bronzes," by Mr. Meigh.

"Manufacture of a Rectangular Tank of 7 Tons in Acid-resisting Iron, with Application of Simplified Methods derived from Mass-production Methods," by Mr. Simorre.

"Effects of Thermal Treatment on Black-Heart Malleable," by Mr. Leroyer.

"Special Irons," by Messrs. Guillet and Ballay.

"Nitrarding," by Mr. Guillet.

"Occluded Oxygen in Cast Irons," by Messrs. Cournot and Le Thomas, and Miss Haim.

"Influence of Molybdenum on Cast Iron. (1) Ordinary Irons, (2) Malleable Irons," by Messrs. Cournot and Challansonnet.

"Influence of Titanium on Cast Iron," by Mr. Challansonnet.

"Influence of Nickel and Chrome on the Annealing of Cast Iron," by Mr. Thiery and Miss Lacroix.

"Influence of Aluminium on Cast Iron," by Mr. Ploye.

"Life of Liquid Metals," by Mr. Courty.

"Graphitisation of Cast Irons at Moderate Temperatures from 400 deg. C. to 600 deg. C.," by Messrs. Le Thomas and Morlet.

"Graphitisation in Cast Irons at High Temperatures from 600 deg. C. to 1,000 deg. C.," by Messrs. Le Thomas and Olinger.

"A Study of Machinability of Cast Irons," by Mr. Hénon.

"Variations in Deflection of Cast Iron under Transverse Test," by Mr. Guillemeau.

"Welding Cast Irons," by Mr. Granjou.

"Hardening Action of Silicon on Tin Bearing, Copper, Nickel and Bronzes," by Messrs. Ballay and Le Thomas.

"Examples of Rational Organisation for Non-quantity Production," by Mr. Bloch.

"Prevention of Accidents in the Foundry," by Mr. Ageron.

"A Study of Cast Irons with Low Carbon Content," by Mr. Portier.

"Problems Arising from the Conservation and Development of the Use of Castings," by Mr. Renaud.

"Report on the Work of the Commission for an International Foundry Dictionary," by Mr. J. M. Espana (chairman).

Catalogues Received.

Automatic Electric Switch.—We recently reviewed, under this heading, two catalogues emanating from the Metropolitan Vickers Electrical Company, Limited, Trafford Park, Manchester, entitled "Single-Phase Motors and Fractional Horse-Power Motors." We have now received a further publication describing and illustrating a new air-break automatic switch which this company has recently developed and which should go far to replacing the ordinary switch and fuse for requirements within its capacity. These switches are designed, *inter alia*, to be installed right on the job to be actuated, where the machine would be provided with a motor and a fast-and-loose pulley. It thereby eliminates the loose pulley, and reduces the time of motor operation. This catalogue is presented in the form of a folder. This is a specific case where a folder can with advantage be used, because it only calls for an expenditure of less than two pounds and, moreover, possesses the widest range of application. Again, the folder, unlike most, is sensibly folded and does not present half the matter upside down—a common fault of this type of publicity.

Wheelbarrows. — The Sterling Foundry Specialties, Limited, Bedford, in Leaflet No. W39, illustrate and describe a line of wheelbarrows for which they are justly renowned. The illustration on page 2 is an excellent example of publicity from an engineering angle, and one that should be emulated wherever possible. After a general description of the wheelbarrows, the reader is taken through each component and shown the "whys and wherefores" of its form and inclusion. Pages 5 to 10 describe, illustrate and dimension the modifications available to the various activities—contractors, coke, concrete, pig-iron, and so on. Finally, on page 11, each type and size of barrow is priced.

This Week's News in Brief.

Trade Talk.

THE TWIN-SCREW CRANE PONTOON recently completed by Messrs. Harland & Wolff, Limited, Govan, Glasgow, for service in Durban Harbour has carried out successful tests in the Gareloch.

AN EXPENDITURE of over £77,000 on new switchgear is proposed by the Electricity Committee of the Wolverhampton Corporation. The main contract of £43,813 is to be given to the General Electric Company, Limited.

LAST WEEK Messrs. T. E. Gray & Company, Limited, of 119, High Holborn, London, W.C.1, put into commission at their quarries a 212-h.p. Campbell crude-oil engine. This installation was made necessary by the increasing demand for "Silacene."

THE SCOTTISH IDEAL HOME EXHIBITION is to be held in the Kelvin Hall, Glasgow, from October 5 to October 29, 1932. An exhibit which promises to be of interest for founders is one tracing the development of the fireside from the earliest times to the present time.

TWO MOTOR FISHING VESSELS were launched by Messrs. Noble & Company, Limited, shipbuilders, Fraserburgh, for Campbeltown owners. The boats have been fitted with all the most modern equipment, and the propelling machinery consists of Kelvin Ricardo engines capable of giving a speed of 7½ knots.

MINING & INDUSTRIAL EQUIPMENT, LIMITED, report having received the following orders: Six Hum-mer screens, two Rovac filters, two Raymond pulverisers and an Impax pulveriser, one Lopulco mill, and one Hardinge ball mill, for firms in England: one grit pump for South Africa, and one Hardinge ball mill for Russia.

THE WELL-KNOWN HENSCHEL FIRM, of Cassel, reports a further loss of £133,000 for the past year, increasing the total loss carried forward to £207,000. In 1913 the firm built 870 locomotives, of which 370 found foreign purchasers. Last year the output was 171 locomotives, of which 130—representing half the total German locomotive export—went abroad.

IN ADDITION to the usual quarterly allocations to infirmaries and other charitable institutions, amounting to £446 10s. 7d., for the quarter ended June 30, the employees of the Carron Company, Falkirk, have made donations from the accumulated interest on their works holiday fund to infirmaries in Falkirk, Edinburgh and Glasgow totalling £210 14s. 3d.

SUBJECT TO AN AGREEMENT with the Central Electricity Board, the Corporation of Brighton has placed with Messrs. C. A. Parsons & Company, Limited, Newcastle-upon-Tyne, an order for a 30,000-kw. turbo-alternator and condensing plant for the Southwick power station, Brighton. The value of the contract is in the neighbourhood of £50,000.

THE STANTON IRONWORKS COMPANY, LIMITED, announces that of the provisional allotments of 302,575 ordinary shares of £1 each recently offered to existing ordinary shareholders at 25s. per share, 299,429 have been accepted. Applications for surplus shares number nearly 150,000, but, in view of the small number available, the directors feel it is impossible to allot them equitably and accordingly the deposits paid with these applications have all been returned.

THE PARTNERSHIP between Messrs. Bernard A. Woodward and Robert H. Woodward, carrying on business as brassfounders, at Legge Lane, Birmingham, under the style of Walker & Woodward, was dissolved as and from June 30, 1932, by mutual consent, Mr. Bernard A. Woodward having retired from the firm. The business will in future be carried on by Mr. Robert H. Woodward, in conjunction with Mr. Robert Arthur Woodward, under the same style.

ON AUGUST 1 a fire occurred at the Gothic Iron Works of Messrs. R. & A. Main, Limited, Camelon, Falkirk. The outbreak occurred in the test-room and rooms adjoining the laboratory. The fire spread rapidly, but the flames were kept in check by the works fire brigade until the Falkirk Brigade arrived, when the fire was soon extinguished. The test-room and laboratory both contained material of a highly inflammable nature, and but for the prompt action of the firm's brigade the damage might have been very serious. As it is, business will not be interfered with.

IN VIEW OF THE DEVELOPMENT of the Diesel engine for motor traction and power generally, it is interesting to note that the old-established business of C. F. Wilson & Company, Limited, crude-oil engine manufacturers, Constitution Street, Aberdeen, has been purchased by a number of local gentlemen with a view of attracting additional industry to the city. The company has been reconstructed and registered under the name of C. F. Wilson & Company (1932), Limited, and steps are being taken to permit of the manufacture of crude-oil Diesel engines on an extensive scale.

IN CO-OPERATION WITH Messrs. Kodak, Limited, a standard-size film showing the works of Edgar Allen & Company, Limited, has been copied and brought down to 16-mm. size, suitable for reproduction by machines showing film of the 16-mm. size. The film is obtainable on loan from the Kodascope Library, Kodak House, Kingsway, London, W.C.2. and schools, technical colleges, institutes, etc., desiring to borrow this film for display should write to that address for particulars. The film is available for all 16-mm. projectors, shows various processes in the manufacture of tool steel, steel castings, etc., and is of great pictorial interest.

MESSRS. HALL & PICKLES, LIMITED, Sheffield, have undertaken the supply of a new electrical resistance alloy called "Kanthal," and hold the exclusive selling rights in this country. It will withstand up to 1,325 deg. C. for long periods, without the usual disadvantages associated with non-metallic materials. It is claimed to possess a much higher specific resistance, and lower specific gravity, than the nickel-chromium alloys, and, when in the presence of sulphur, is attacked only to a very small degree. The alloy is produced in strip (Kanthal "A1"), wire (Kanthal "A"), wire and tape (Kanthal "D"), castings and tubes for pyrometer sheaths.

THE NATIONAL COMMITTEE appointed, at the request of the Import Duties Advisory Committee, to prepare a scheme for the reorganisation of the iron and steel industry, has already presented a report to Sir George May's Committee which gives a general outline of the work the national and regional and special committees are doing. Good progress has been made during the past few weeks. The various regional committees are continuing their investigations and will continue to hold meetings throughout this month. It is expected that it will be possible to send to the Import Duties Advisory Committee not later than the end of September a report showing in detail the work which the various committees have accomplished.

ALTHOUGH THE ORDER for the building of the new 22,000-ton liner "Queen of Bermuda" did not go to the Tyne, satisfaction has been felt at the number of sub-contracts which have been let in the district. These include:—Sunderland Forge & Engineering Company, Limited, electrical wiring and fittings; Clarke, Chapman & Company, Limited, Gateshead, capstans, windlasses and winches; Darlington Forge, Limited, rudder stock; British Ropes, Limited, Gateshead, wire hawsers and reels, rigging wire, etc.; Wailes Dove Bitumastic, Limited, Hebburn, bituminous coverings; Dorman, Long & Company, Limited, Middlesbrough, mild-steel bars; Consett Iron Company, Limited, plates and sections, etc. The vessel is being built by Messrs. Vickers-Armstrongs, Limited, at Barrow-in-Furness.

Company Reports.

Bengal Iron Company, Limited.—Profit, £32,132; debit balance brought in, £30,774; available, £1,357; depreciation, £35,520; debenture interest, £60,721; written off debenture discount account, £1,000; income-tax reserve, £17,000; debit balance carried forward, £112,884.

Thos. Bolton & Sons, Limited. — Manufacturing profit, £50,733; balance on revenue account, £31,944; brought in, £82; debenture interest and financial charges, £29,324. On account of the position of the copper market, it is considered advisable to revalue at current rates the stock held. This involves a reduction of £16,000, and when this amount is taken to account, together with another non-recurring charge of £11,734, for compensation to retired officials, there remains a debit balance of £25,032 to go forward.

Personal.

PROF. J. S. S. BRAME has joined the board of Messrs. Alexander Duckham & Company, Limited.

MR. JOHN T. BATEY, managing director of the Hebburn shipbuilding yard of Messrs. R. & W. Hawthorn, Leslie & Company, Limited, has just celebrated his 70th birthday.

MR. ARNOLD CARR has been appointed manager of the foundry supply and equipment department of Messrs. T. W. Ward, Limited. This will involve his removal from the London office to Albion Works, Sheffield.

MR. PERCY LISTER has been appointed by the Secretary for Mines to be one of the representatives of consumers of coal on the Committee of Investigation for the Forest of Dean district in place of the late Mr. A. Glyn Watkins.

CAPTAIN O. E. H. LESLIE has recently left the Vickers works of the English Steel Corporation, Limited, Sheffield, where for the past two years he has been manager of the gun plant. His total service with the Vickers firm was 20 years.

MR. D. M. DAVIDSON, who has been in England for the summer, sails to-day for South Africa. Mr. Davidson is a director of the East Rand Engineering Company, Limited, New Industrial Sites, Germiston, Transvaal, which is one of the largest foundry concerns in the Union.

MR. JOHN IRVINE, of Bonnybridge, a metal plate worker employed by Messrs. Smith & Wellstood, Limited, Columbia Foundry, has been awarded first prize in the recent examination held under the auspices of the City and Guilds of London Institute in Grade 1. The award is accompanied by a bronze medal.

THE STAFF OF Messrs. John G. Stein & Company, Limited, Castlecary Brick Works, met in the head office on August 3 to felicitate Mr. Robert Lind, a popular member of the staff, on the occasion of his marriage. The manager, Mr. Charles Taylor, on behalf of all members of the staff, asked Mr. Lind to accept a handsome oak writing bureau and bookcase.

Wills.

WATSON, T. H., of Boldre, Hants, iron and steel merchant	£5,323
GRAHAM, SIR WILLIAM, of Barry Island, Glamorgan, engineer	£65,001
HERBERT, ERNEST NICHOLAS LE QUESNE, a director of Allied Ironfounders, Limited, personal estate	£14,049
BROTHERTON, JOHN, J.P., of Helsby, Cheshire, formerly general manager of the British Insulated Cable Works, Helsby	£33,481
DAVIDSON, ALBERT, of Sheffield, managing director of the Heeley Silver Rolling & Wire Mills, Limited, and the Vololo Corrugated Steel Cask Company, Limited	£49,705

Obituary.

WHILST ENGAGED on a staging in the bath-moulding shop of Messrs. Saunders & Connor, Limited, Barrhead, Mr. Thomas Bryce was killed. It is supposed that he accidentally touched a live wire. He fell about 15 ft. and when picked up was found to be dead.

MR. THOMAS CLARK, one of the men injured in the naphtha explosion at the Blochairn works of the Steel Company of Scotland, Limited, a week ago, has succumbed to the effects of burning. Two of the other men are still in the infirmary, but their condition is slightly improved.

THE DEATH OCCURRED very suddenly on August 2 of Mr. John Neish, of 21, Anderson Drive, Denny, who was for over forty years foreman with Messrs. Cruikshanks & Company, Limited, Denny Iron Works. Although the state of Mr. Neish's health had given cause for some anxiety in recent months and he had been advised to rest by his medical adviser, no immediate anxiety was felt, and he was about as usual during the day. Whilst reading at night he suddenly collapsed and expired almost immediately. The deceased served his apprenticeship as a patternmaker at Denny Iron Works, and after a term of work in Glasgow was employed in Birmingham for some considerable time. He then returned to Denny and a few years ago assumed an active interest in Broomhill Brickworks, Bonnybridge.

Raw Material Markets.

The iron and steel markets are exhibiting very little activity, and, even when allowance is made for the effect of the holiday season, conditions still remain disappointing. The demand from consumers has shown no improvement during the past week. Prices remain steady, however, producers being convinced that any reductions would have little effect upon the general situation. Whether the latter will show any improvement during the autumn it is difficult to say, but in view of the present depression existing in the heavy industries, it seems inevitable that recovery will take a long time, especially because of the heavy stocks of unsold material existing in this country.

Pig-Iron.

MIDDLESBROUGH.—Shipments of pig-iron from the Tees last month were the lowest since 1926, and there have been no signs of improvement so far this month. Only a few small parcels are being sent abroad, the needs of Scottish consumers are limited, and sales to the local foundries are showing unusual contraction. Many of the latter are using Midlands iron, as the Cleveland makers refuse to make any reduction in their local minimum prices. This minimum scale of prices to other than Scottish consumers is as follows:—No. 1 Cleveland foundry iron, 61s.; No. 3 Cleveland G.M.B., 58s. 6d.; No. 4 foundry, 57s. 6d.; No. 4 forge, 57s. per ton, f.o.t. or f.o.b.

The number of hematite furnaces in blast on the East coast is now only three, but the reduction in output has failed to strengthen the market as heavy tonnages of hematite are still held in various hands. The general quotation for mixed numbers is 61s. per ton, but this could possibly be shaded. On the North-West Coast, Bessemer mixed numbers remain steady, in the absence of trade, at 66s. per ton.

LANCASHIRE.—The foundries remain generally short of business, although slightly better conditions are to be seen in the light-castings and textile machinery branches. A few replacement contracts covering the next two or three months have been booked, but most of the past week's turnover has consisted of small quantities for early delivery. For delivery to users in the Manchester price zone, Staffordshire and Derbyshire No. 3 iron is on offer at 67s. per ton, with Cleveland at around 67s. also, Northamptonshire at 65s. 6d., Derbyshire forge at 62s., Scottish brands of No. 3 at 84s. 6d., and West Coast hematite iron at around 81s. Offers of Indian iron are still reported at from about 67s. to 77s. 6d. per ton, according to grade, including delivery in the Manchester district.

MIDLANDS.—Many foundries in the district were idle until the middle of this week, and stocks of foundry iron are accumulating rather rapidly at several producing works. The next week or two should see some improvement in the position, particularly at the light-castings works, but the heavy engineering and shipbuilding industries can offer little cause for optimism at the moment. Prices were recently reviewed by the makers, but no change was made, current quotations being 62s. 6d. for Northants No. 3 and 66s. for Derbyshire, Lincolnshire and North Staffordshire No. 3, including delivery to Birmingham and Black Country stations.

SCOTLAND.—The effect of several local holidays this week serves only to emphasise the extreme contraction of trade. There is still only one furnace in Scotland operating on foundry iron, the price of which remains at 69s. 6d. per ton f.o.t. furnaces, with a minimum of 2s. 6d. extra for No. 1 grade. No. 3 Middlesbrough is being quoted at not more than 55s. 6d. f.o.t. Falkirk, with other English brands at slightly less. Continental iron, either basic or foundry, is not being offered.

Coke.

The foundry-coke market is very quiet. Business is confined to small lots for early delivery, although six-months' purchases can be arranged at current rates. Best Durham foundry grades are quoted at 37s. 6d. per ton, with other qualities at 35s. The prices of Welsh foundry coke depend upon the quality and quantity involved, the figures ranging from 30s. up to 45s. per ton, delivered Birmingham and district.

Steel.

Business remains limited in the finished-steel market. Shipbuilding requirements are at the lowest level for years, and none of the other steel-consuming industries is taking its normal quota of raw material. Small steel bars continue to come through from the Continent at prices considerably below the lowest quoted by the home manufacturers. Prices of finished steel were recently reviewed at a meeting of the producers, but no change was made. The long-promised recovery in the semis market has yet to be realised. Owing to the restricted output of finished products, consumers' stocks of semis are still considerable. The home works, however, are driving a moderate trade, although still undercut from the Continent in several districts.

Scrap.

A better trade in small parcels of cast-iron scrap is being done on the Cleveland market, affording proof of the shortness of stocks at the foundries. Small parcels of ordinary heavy cast iron are saleable at 35s., but no more than 36s. is offered for good machinery quality. Buyers of light castings can cover their requirements at 30s. Business in cast-iron scrap in the Midlands is practically at a standstill. Heavy machinery metal in cupola sizes is offered at 47s. 6d. delivered and clean light metal at 35s. 6d. delivered. Deliveries of scrap have now been resumed in Scotland, but the foundries report their requirements to be fully covered, and little new business can be done. In South Wales, heavy cast iron in large pieces and furnace sizes appears to be in better request and is slightly firmer at 40s. to 42s. 6d. Good cast-iron machinery scrap continues to have a limited demand, but prices are firmer, to correspond with the advance in heavy material, at 45s. to 47s. 6d. per ton.

Metals.

Copper.—The rise in the sterling quotation on the London market has been mainly due to the weakness in the exchange, but the c.i.f. Europe cents quotation has also firmed up, about 5.45 being the current level for electrolytic. There has also been a welcome increase in buying in France and Germany, for three and six months' delivery. There has also been some increase in buying in this country, and it is apparent that the small supplies of very cheap metal have now been absorbed.

Closing quotations :—

Cash.—Thursday, £28 5s. to £28 6s. 3d.; Friday, £28 13s. 9d. to £28 15s.; Monday, £30 12s. 6d. to £30 15s.; Tuesday, £30 2s. 6d. to £30 5s.; Wednesday, £29 1s. 3d. to £29 2s. 6d.

Three Months.—Thursday, £28 3s. 9d. to £28 5s.; Friday, £28 11s. 3d. to £28 12s. 6d.; Monday, £30 12s. 6d. to £30 13s. 9d.; Tuesday, £30 2s. 6d. to £30 5s.; Wednesday, £29 to £29 2s. 6d.

Tin.—This metal continues to maintain its improved position, which seems largely due to a wave of market optimism coinciding with a period of unexampled restriction of output. Queries are already being put, however, as to the real soundness of the market, especially in view of the disappointing July consumption-and-supply statistics. Buying by consumers has been limited this week.

Official closing prices :—

Cash.—Thursday, £136 to £136 5s.; Friday, £138 10s. to £138 15s.; Monday, £139 5s. to £139 10s.; Tuesday, £140 to £140 5s.; Wednesday, £140 5s. to £140 10s.

Three Months.—Thursday, £137 15s. to £138; Friday, £139 15s. to £140; Monday, £141 to £141 5s.; Tuesday, £141 10s. to £141 15s.; Wednesday, £141 15s. to £142.

Spelter.—Inquiries from consumers have shown a slight increase, probably owing to the firmer tone of the market, but the daily turnover shows little change. Business also remains very restricted on the Continent.

Daily fluctuations :—

Ordinary.—Thursday, £12 13s. 9d.; Friday, £12 15s.; Monday, £13 3s. 9d.; Tuesday, £13 3s. 9d.; Wednesday, £12 15s.

Lead.—At the moment, there has been little improvement in the demand, but a slightly better trade is being done in lead manufactures, and few consumers have very large stocks, so that the outlook is slightly more optimistic.

The week's prices have been :—

Soft Foreign (Prompt).—Thursday, £10 5s.; Friday, £10 8s. 9d.; Monday, £10 12s. 6d.; Tuesday, £10 15s.; Wednesday, £10 7s. 6d.

Some Lifting Considerations in a Jobbing Steel Foundry.

In the absence of the author, Mr. F. J. Hemming, this Paper, presented before the Annual Congress of the Institute of British Foundrymen and printed in our last issue, was introduced by Mr. R. Wilson.

Mr. W. R. Cooper, speaking on the diagram showing the ground plan of building and lay-out of distributing runway for moulding sand, said that there was a danger when the foundry was working at full pressure and the mill was turning out sand as fast as it could be worked, the crane which carried the sand on this runway was apt to be over-worked. When the crane had to travel from the mill to the far end of the shop there must be occasions when it came back unloaded and that was a matter for organisation to see that no time was lost. There were occasions when most of the moulders were using sand as fast as it could be produced and would not require the overhead crane. It would thus be standing idle while the runway crane was being overworked.

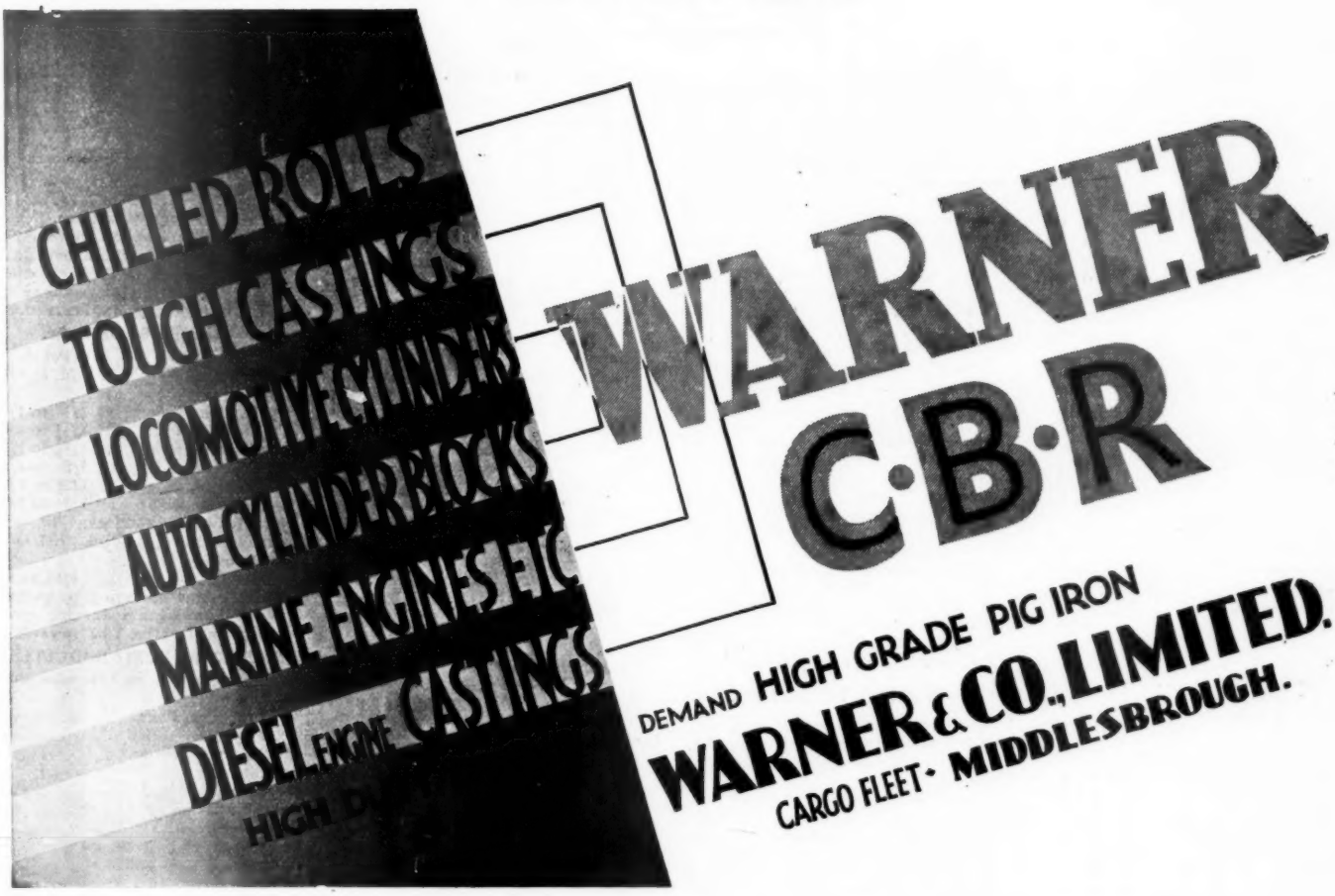
Mr. Wilson said that this lay-out was designed purely for the distribution of sand, and it was simple organisation with sufficient equipment of bins so that there could be a continual supply of sand to the moulders. The side cranes in Fig. 1 were put in after the shop was designed. It was found that practically 90 per cent. of the lifts could be carried out by these side cranes which had full control of 80 per cent. of the width of the shop.

Publication Received.

Welding Electrodes. — The Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, in Publication No. 7783/10, describe the characteristics of a coated welding electrode which has been developed by the co-operation of the engineers and research department. It is claimed to be free flowing and it is coated with a flux of such a character that the rod can be bent without breaking or cracking the covering. The average tensile strength of the weld metal is of the order of 31 tons per sq. in. Special attention has been given to the packing so as to ensure safety of carriage and ease of access. The electrodes are to be known as "Emvee Type R." This little pamphlet contains 16 pages and includes 8 pages of data designed to be of use to plate and sheet-metal workers.

Cylinder Wear in Marine Diesel Engines.—The M.S. "Meonia," built in 1927 for the East Asiatic Company, is equipped with two six-cylinder four-stroke single-acting engines rated at 2,500 i.h.p. each and built by Burmeister & Wain. These engines have already made fourteen return voyages to the East and have covered a total distance of 280,000 miles. The cylinders examined after a recent trip of 10,000 miles showed a maximum wear in any one cylinder of 1.85 millimetres, whilst in other cylinders the wear does not exceed 1.45 millimetres. The M.S. "Gripsholm" is equipped with two four-stroke, double-acting engines of 6,500 i.h.p. each, the first of their type to be constructed. These engines were placed into service six and a-half years ago and have travelled 477,918 miles. The maximum cylinder wear is now only 3.5 millimetres and according to the chief engineer many of the cylinders show far less wear than this.

XUM



CAST IRON FLANGED PIPES

2 in.—12 in. & CONNECTIONS. to 24 in. dia.

WE HAVE FIFTY-TWO YEARS OF ACCUMULATED EXPERIENCE AND METAL PATTERNS.

JAMES & RONALD RITCHIE, LTD.,

Telephone: 3852 (2 Lines). **MIDDLESBROUGH.** Telegrams: "Ritchie, Middlesbrough."

WEEKLY PRICE CURRENT.

COPPER.

	£	s.	d.
Standard cash	29	1	3
Three months	29	0	0
Electrolytic	34	0	0
Tough	32	0	0
Best selected	32	10	0
Sheets	57	0	0
India	43	10	0
Wire bars	35	10	0
Do., Sept.	35	5	0
Do., Oct.	25	0	0
Ingot bars	35	10	0
H.C. wire rods	37	15	0
Off. av. cash, July	26	2	5⅝
Do., 3 mths., July	25	13	6¾
Do., Sttlmnt., July	26	1	10⅝
Do., Electro, July	29	10	0
Do., B.S., July	28	15	10
Do., wire bars, July	29	17	10¾
Solid drawn tubes			9½d.
Brazed tubes			9½d.
Wire			6¼d.

BRASS.

Solid drawn tubes	8¾d.
Brazed tubes	10¾d.
Rods, drawn	7¼d.
Rods, extd. or rlld.	4¾d.
Sheets to 10 w.g.	7¼d.
Wire	7¼d.
Rolled metal	6¾d.
Yellow metal rods	4d.
Do. 4 × 4 Squares	5¼d.
Do. 4 × 3 Sheets	5¼d.

TIN.

	£	s.	d.
Standard cash	140	5	0
Three months	141	15	0
English	142	0	0
Bars	143	15	0
Straits	144	15	0
Australian	143	0	0
Eastern	146	5	0
Banca	150	0	0
Off. av. cash, July	125	19	5⅞
Do., 3 mths., July	127	12	3½
Do., Sttlmt., July	125	19	0⅞

SPELTER.

	£	s.	d.
Ordinary	12	15	0
Remelted	12	10	0
Hard	10	12	6
Electro 99.9	15	15	0
English	14	5	0
India	12	10	0
Zinc dust	20	0	0
Zinc ashes	2	0	0
Off. aver., July	11	15	6¾
Aver. spot, July	11	11	10⅞

LEAD.

	£	s.	d.
Soft foreign ppt.	10	7	6
Empire	11	7	6
English	12	10	0
Off. average, July	9	19	8⅜
Average spot, July	9	16	4⅜

ZINC SHEETS, &c.

	£	s.	d.
Zinc sheets, English	22	10	0
Do., V.M. ex-whf.	23	0	0
Rods	26	0	0
Boiler plates			—
Battery plates			—

ANTIMONY.

	£	s.	d.	£	s.	d.
English	35	0	0 to 42	10	0	
Chinese				23	10	0
Crude				16	0	0

QUICKSILVER.

	£	s.	d.
Quicksilver	9	5	0

FERRO-ALLOYS AND STEEL-MAKING METALS.

	£	s.	d.
Ferro silicon—			
25%	8	5	0
45/50%	13	10	0
75%	19	10	0
Ferro-vanadium—			
35/50%	12/8 lb. Va.		
Ferro-molybdenum—			
70/75% c. free, of Mo.	6/3 per lb.		
Ferro-titanium—			
23/25% carbon-free	11½d. lb.		
Ferro-phosphorus, 20/25%	£22	0	0
Ferro-tungsten—			
80/85%	1/9 lb.		
Tungsten metal powder—			
98/99%	2/- lb.		
Ferro-chrome—			
2/4% car.	£34	0	0
4/6% car.	£25	5	0
6/8% car.	£24	10	0
8/10% car.	£23	7	6
Ferro-chrome—			
Max. 2% car.	£37	0	0
Max. 1% car.	£46	15	0
Max. 0.70% car.	£45	7	6
70% carbon-free	1/1 lb.		
Nickel—80/99.5%	£240 to £245		
"F" nickel shot	£216	0	0
Ferro-cobalt	7/9 lb.		
Aluminium 98/99%	£95	0	0
Metallic chromium—			
96/98%	2/9 lb.		
Ferro-manganese (net)—			
76/80% loose	£10 15 0 to £11 5 0		
76/80% packed	£11 15 0 to £12 5 0		
76/80% export (nom.)	£9 0 0		
Metallic manganese—			
94/96% carbon-free	1/4½ lb.		

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 3/16 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP.

	£	s.	d.	£	s.	d.
South Wales—						
Heavy steel	1	18	6 to	2	0	0
Bundled steel and shrngs.	1	14	0 to	1	15	0
Mixed iron and steel				1	15	0
Heavy cast iron	2	0	0 to	2	2	6
Good machinery	2	5	0 to	2	7	6
Cleveland—						
Heavy steel				1	15	0
Steel turnings				1	10	0
Cast-iron borings				1	2	6
Heavy forge				2	10	0
W.I. piling scrap				2	2	6
Cast-iron scrap	1	15	0 to	1	16	0
Midlands—						
Light cast-iron scrap				1	15	6
Heavy wrought iron				2	2	6
Steel turnings, f.o.r.				0	18	0
Scotland—						
Heavy steel				1	15	0
Ordinary cast iron				2	0	0
Engineers' turnings				1	9	0
Cast-iron borings				1	9	0
Wrought-iron piling				1	19	0
Heavy machinery				2	4	0

London—Merchants' buying prices delivered yard.

	£	s.	d.
Copper (clean)	22	0	0
Brass	13	0	0
Lead (less usual draft)	7	0	0
Tea lead	5	0	0
Zinc	5	5	0
New aluminium cuttings	72	0	0
Braziery copper	18	0	0
Gunmetal	17	0	0
Hollow pewter	70	0	0
Shaped black pewter	50	0	0

PIG-IRON.

(f.o.t. unless otherwise stated.)

N.E. Coast—	
Foundry No. 1	61/-
Foundry No. 3	58/6
Foundry No. 4	57/6
Forge No. 4	57/-
Hematite No. 1	61/6
Hematite M/Nos.	61/-
N.W. Coast—	
Hem. M/Nos. d/d Glas.	72/-
,, d/d Birm.	84/6
Malleable iron d/d Birm.	117/6
Midlands—	
Staffs common*	—
,, No. 4 forge*	61/-
,, No. 3 fdry.*	66/-
Shrops basic	—
,, Cold blast, ord.	—
,, ,, roll iron	—
Northants forge*	57/6
,, fdry. No. 3*	62/6
,, fdry. No. 1*	65/6
Derbyshire forge*	61/-
,, fdry. No. 3*	66/-
,, fdry. No. 1*	69/-
,, basic*	—

*d/d Black Country dist.

Scotland—	
Foundry No. 1	72/-
,, No. 3	69/6
Hem. M/Nos. d/d	68/6
Sheffield (d/d district)—	
Derby forge	58/6
,, fdry. No. 3	63/6
Lincs forge	—
,, fdry. No. 3	63/6
E.C. hematite	74/6
W.C. hematite	83/6
Lancashire (d/d eq. Man.)—	
Derby forge	62/-
,, fdry. No. 3	67/-
Staffs fdry. No. 3	67/-
Northants fdry. No. 3	65/6
Cleveland fdry. No. 3	67/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	84/6
Clyde, No. 3	84/6
Monkland, No. 3	84/6
Summerlee, No. 3	84/6
Eglinton, No. 3	84/6
Gartsherrie, No. 3	84/6
Shotts, No. 3	84/6

FINISHED IRON AND STEEL.

Usual District deliveries for iron; delivered consumers' station for steel.

	£	s.	d.	£	s.	d.
Iron—						
Bars (cr.)	9	5	0 to	9	15	0
Nut and bolt iron	7	15	0 to	8	10	0
Hoops	10	10	0 to	12	0	0
Marked bars (Staffs) f.o.t.				12	0	0
Gas strip	10	10	0 to	12	0	0
Bolts and nuts, ¾ in. × 4 in.				12	0	0
Steel—						
Plates, ship, etc.	8	15	0 to	8	17	6
Boiler plts.	8	7	6 to	9	5	0
Chequer plts.				10	7	6
Angles				8	7	6
Tees				9	7	6
Joists				8	15	0
Rounds and squares, 3 in. to 5½ in.				9	7	6
Rounds under 3 in. to ½ in. (Untested)			6 12 6	& up.		
Flats—8 in. wide and over				8	12	6
,, under 8 in. and over 5 in.				8	17	6
Rails, heavy	8	5	0 to	8	10	0
Fishplates				12	0	0
Hoops (Staffs)				9	10	0
Black sheets, 24g.	8	0	0 to	8	10	0
Galv. cor. shts.	9	5	0 to	9	15	0
Galv. flat shts.	9	15	0 to	10	15	0
Galv. fencing wire, 8g. plain				12	10	0
Billets, soft	4	17	6 to	5	7	6
Billets, hard				6	12	6
Sheet Bars	4	15	0 to	5	5	0
Tin Bars				4	15	0

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	10d.
Sheet to 10 w.g.	11d.
Wire	11½d.
Rods	10d.
Tubes	15½d.
Castings	12d.

Delivery 3 cwt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated

	Dols.
No. 2 foundry, Phila.	14.34
No. 2 foundry, Valley	14.50
No. 2 foundry, Birm.	11.00
Basic	15.39
Bessemer	16.89
Malleable	16.39
Grey forge	16.39
Ferro-mang. 80%, seaboard	68.00
O.-h. rails, h'y, at mill	43.00
Billets	26.00
Sheet bars	26.00
Wire rods	37.00
	Cents.
Iron bars, Phila.	2.11
Steel bars	1.60
Tank plates	1.60
Beams, etc.	1.60
Skelp, grooved steel	1.60
Skelp, sheared steel	1.60
Steel hoops	1.55
Sheets, black, No. 24	2.20
Sheets, galv., No. 24	2.85
Wire nails	1.95
Plain wire	2.20
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$4.75

COKE (at ovens).

Welsh foundry	20/- to 22/6
,, furnace	16/- to 16/6
Durham and Northumberland—	
,, foundry	21/- to 25/-
,, furnace	12/9
Midlands, foundry	—
,, furnace	—

TINPLATES.

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box	15/- to 15/6
,,	28×20 ,,	30/- to 31/-
,,	20×10 ,,	22/- to 22/3
,,	18¾×14 ,,	15/6 to 15/9
C.W.	20×14 ,,	13/- to 13/3
,,	28×20 ,,	—
,,	20×10 ,,	—
,,	18¾×14 ,,	—

SWEDISH CHARCOAL IRON & STEEL.

Pig-iron	£6	0	0 to	£7	0	0
Bars-hammered, basis	£16	10	0 to	£17	0	0
Bars and nail-rods, rolled, basis	£15	17	6 to	£16	5	0
Blooms	£10	0	0 to	£12	0	0
Keg steel	£32	0	0 to	£33	0	0
Faggot steel	£18	0	0 to	£23	0	0
Bars and rods dead soft, st'l	£10	0	0 to	£12	0	0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis o Kr. 18.16 to £1.]

DAILY FLUCTUATIONS.

Standard Copper (cash).

		£	s.	d.		
Aug.	4 ..	28	5	0	inc.	17/6
,,	5 ..	28	13	9	,,	8/9
,,	8 ..	30	12	6	,,	38/9
,,	9 ..	30	2	6	dec.	10/-
,,	10 ..	29	1	3	,,	21/3

Electrolytic Copper.

		£	s.	d.		
Aug.	4 ..	31	15	0	inc.	15/-
,,	5 ..	33	0	0	,,	25/-
,,	8 ..	34	10	0	,,	30/-
,,	9 ..	34	0	0	dec.	10/-
,,	10 ..	34	0	0	No change	

Standard Tin (cash).

		£	s.	d.		
Aug.	4 ..	136	0	0	inc.	60/-
,,	5 ..	138	10	0	,,	50/-
,,	8 ..	139	5	0	,,	15/-
,,	9 ..	140	0	0	,,	15/-
,,	10 ..	140	5	0	,,	5/-

Tin (English ingots).

		£	s.	d.		
Aug.	4 ..	137	15	0	inc.	60/-
,,	5 ..	140	5	0	,,	50/-
,,	8 ..	141	5	0	,,	20/-
,,	9 ..	141	15	0	,,	10/-
,,	10 ..	142	0	0	,,	5/-

Spelter (ordinary).

		£	s.	d.		
Aug.	4 ..	12	13	9	inc.	7/6
,,	5 ..	12	15	0	,,	1/3
,,	8 ..	13	3	9	,,	8/9
,,	9 ..	13	3	9	No change	
,,	10 ..	12	15	0	dec.	8/9

Spelter (Electro, 99.9 per cent.).

		£	s.	d.		
Aug.	4 ..	15	2	6	inc.	5/-
,,	5 ..	15	5	0	,,	2/6
,,	8 ..	15	15	0	,,	10/-
,,	9 ..	15	15	0	No change	
,,	10 ..	15	15	0	,,	,,

Zinc Sheets (English).

		£	s.	d.		
Aug.	4 ..	22	10	0	No change	
,,	5 ..	22	10	0	,,	,,
,,	8 ..	22	10	0	,,	,,
,,	9 ..	22	10	0	,,	,,
,,	10 ..	22	10	0	,,	,,

Lead (English).

		£	s.	d.		
Aug.	4 ..	12	5	0	inc.	5/-
,,	5 ..	12	5	0	No change	
,,	8 ..	12	10	0	inc.	5/-
,,	9 ..	12	15	0	,,	5/-
,,	10 ..	12	10	0	dec.	5/-

AVERAGE MONTHLY PRICES OF WEST COAST HEMATITE MIXED NUMBERS DELIVERED SHEFFIELD.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1893	46 0½	45 8	45 11	45 7	44 11	44 9½	44 10	45 3	45 0	44 6	44 7	45 8	45 3
1894	45 3	45 3	45 1½	45 1	43 11	43 9½	44 2	44 7	43 7	43 5	43 3	44 3½	44 3½
1895	42 8	42 5½	42 6	42 10	43 10	43 7½	44 10	45 11	49 11	48 9	47 7½	47 7½	45 2½
1896	47 0	48 9	48 9	48 2½	47 3	47 3	46 10	46 10	47 2	48 5	50 7	50 6	48 1½
1897	51 2	49 10	48 5	47 4	47 9½	48 6	47 0	47 3	47 3	47 0	48 3½	47 11	48 2
1898	48 9	48 10	49 4	49 8½	50 10	50 3½	51 0	52 5	53 11	55 8	57 3	56 10	52 1½
1899	59 1	59 9	57 7	59 6	64 7	70 10½	76 7½	72 2	74 3	75 0	78 1½	73 3	68 5
1900	75 3½	76 10	79 10	84 6	81 4	79 1½	83 4	81 5	79 11	76 10	77 8½	68 4	78 8
1901	60 2	59 0	57 9½	57 6½	57 8	57 4½	57 8	61 0	60 0½	59 9	58 7½	56 7	58 7½
1902	56 1	57 9½	59 3½	59 9	59 10½	60 0	60 0	60 8½	61 5	61 2	59 3	59 0	59 6
1903	58 5	58 8	61 1	59 5	57 10	57 3	56 7	56 3	55 9	54 8	52 4	52 4	56 8½
1904	52 8½	53 1	53 7	54 9	54 2	53 2½	52 0	52 5	52 2½	52 7	53 1	55 11½	53 5½
1905	57 9½	56 9	58 1	58 2	56 4	55 8	55 5½	56 7	61 0	68 9	69 9	70 11½	60 5½
1906	70 4½	65 2½	63 4½	63 9	64 5	64 6	64 1	66 2½	67 3	69 4½	72 4½	78 8½	67 5
1907	77 9	72 11	71 10	73 9	79 9½	76 9	77 9	78 4	75 11	72 9½	68 6	66 7	74 4
1908	62 7	59 1	61 6½	61 6½	61 4	59 1	57 9½	56 11	60 2	59 2	58 5½	57 7	59 7½
1909	51 4	56 5	55 3	56 1	56 4	57 0	56 8	58 0	61 0	61 1½	60 7½	61 4	58 1½
1910	64 0½	64 3½	66 10½	67 0½	66 2½	65 4	64 4½	65 6½	65 2	64 10½	64 6	65 6	65 4½
1911	66 9	66 1	64 10	63 1	62 1	62 0	61 2	62 2	62 1	61 1	61 10	64 0	63 1
1912	67 0	67 0	67 0	69 3	71 9½	72 11	75 9½	79 1½	82 2½	85 0	85 3½	86 8	75 9½
1913	86 6	86 6	86 3	85 0	83 6½	80 10½	78 1	76 10½	72 6	71 0	68 0	65 3	78 4½
1914	64 6	65 4½	65 6	64 11½	64 2½	64 0	64 0	68 11½	74 6½	71 0	65 4½	69 9½	66 10½
1915	78 6	100 6	103 1	113 6	111 9	114 0	116 3	115 2½	113 8½	121 1½	131 9½	139 6½	113 3
1916	135 0	135 0	133 4	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	129 2½
1917	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1918	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6	127 6
1919	127 6	127 6	127 6	127 6	180 6	184 3	195 4½	204 6	204 6	204 6	204 6	204 6	174 7
1920	224 9	253 0	245 0	275 0	290 0	295 0	295 0	295 0	295 0	295 0	295 0	280 0	284 11½
1921	253 4	228 4	180 0	180 0	180 0	160 0	160 0	157 6	142 0	128 6	121 0	115 6	167 9½
1922	125 0	117 6	116 0	115 0	115 0	115 0	113 1½	104 0	105 0	105 0	106 3	110 0	112 1½
1923	109 0½	116 5½	133 11½	138 3½	134 2	125 0	115 7½	111 9	110 0	110 0	113 11	115 0	119 5½
1924	115 0	115 0	114 4½	112 6	112 6	112 6	111 0	110 0	110 0	105 4½	102 6	102 6	110 3½
1925	102 6	102 6	100 0	98 6	97 6	95 1½	92 6	90 6	88 3	87 0	88 1½	88 9½	94 3½
1926	90 1½	90 0	89 8½	89 0	89 0	89 0	90 2½	91 9	94 0	97 2½	*	*	91 0
1927	95 4½	95 6	96 6	95 6	95 3	94 0	92 10½	91 6	90 6	90 6	90 6	89 6	93 1½
1928	85 0	85 2	85 5	85 0	85 3	84 9	84 0	83 9	84 0	84 6	83 1	82 6	84 4
1929	82 10½	83 6	85 0	86 9	87 0	87 0	87 3	87 2½	87 6	89 6	89 6	89 10½	86 11
1930	91 6	91 6	91 6	90 0	89 7½	88 0	87 7½	86 6	86 6	86 6	86 6	86 6	88 6½
1931	86 6	84 6	84 6	84 6	84 6	82 6	82 6	81 6	81 6	83 6	83 6	83 6	83 7
1932	83 6	83 6	83 6	83 6	83 6	83 6	83 6	—	—	—	—	—	—

* No prices available.

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EXPERIENCED and well-known Foundry Manager is open to consider new engagement. Has had complete control of large foundries engaged in all branches of ironfoundry work, from small repetition work to castings of 50 tons. (189)

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'Phone: 287 SLOUGH

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4-Ton	"Evans"	£28
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2-Ton	"Evans"	£19

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